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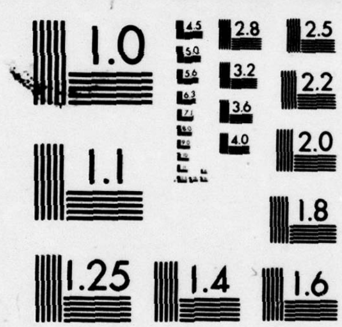

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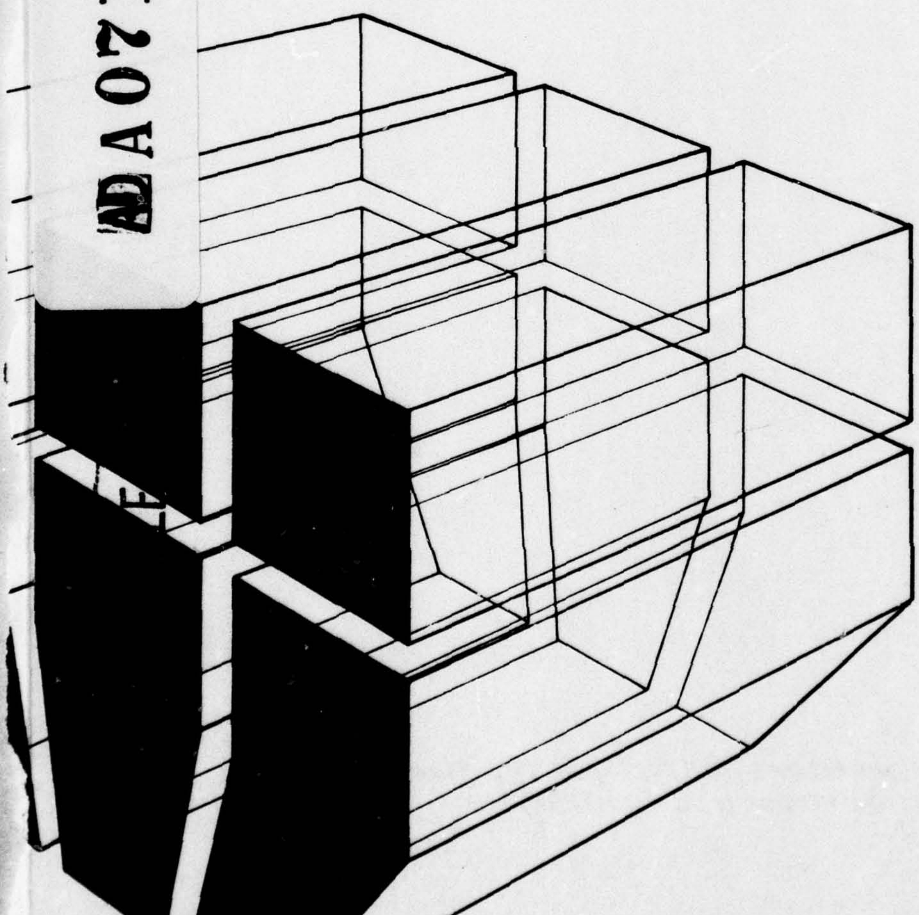
INTERIM REPORT M-263
June 1979
Improved Roofing Materials and Systems

EVALUATION OF ALTERNATIVE REROOFING SYSTEMS



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Errata sheet for E. Marvin, et al., "Evaluation of Alternative Reroofing Systems," Interim Report M-263/ADA071578 (U.S. Army Construction Engineering Research Laboratory [CERL], Jun 79).

Page	Line	
16	7	first column, change 15.24 to 4.65
16	12	second column, change 4.88 to 1.48
17	17	second column, change 5 to 50.8
23	20	second column, change 7200 to 74.3
32	10	second column, change 25 to 83
33	2	first column, change 25 to 83
33	16	first column, change 25 to 83
33	7 from bottom of second column, change 58.5 to 5850	
37	9 from bottom of first column, change 16 to 48	
39	5	first column, change 3 to 10

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This report documents the first phase of a study which evaluates commercially available roofing systems and materials for use in reroofing work at Army installations to determine alternatives to conventional built-up roofing (BUR) that can improve Army roof performance and reduce life-cycle costs.

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FOREWORD

This investigation was performed for the Directorate of Military Programs, Office of Chief of Engineers (OCE), under Project 4A762731AT41, "Military Facilities Engineering Technology"; Task E, "Maintenance and Repair"; Work Unit 031, "Improved Roofing Materials and Systems." The OCE Technical Monitor is R. Russo, DAEN-MPO-B; the FESA Technical Monitor is C. Keaton, FESA-HBG-BG.

This work was performed by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (CERL). Principal Investigators were Mr. E. S. Lindow and Dr. E. Marvin. Dr. G. R. Williamson is Chief of EM.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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EVALUATION OF ALTERNATIVE REROOFING SYSTEMS

1 INTRODUCTION

Background

Current roofing systems at Army installations are generally short-lived because of existing construction, design, contracting, and operation and maintenance (O&M) procedures. In effect, short-lived roofing has created unacceptably high life-cycle costs.

This situation is, in part, a direct result of onsite, labor-intensive construction of conventional built-up roofing (BUR) systems of low-quality workmanship. To eliminate this problem, the U.S. Army Construction Engineering Research Laboratory (CERL) is attempting to identify new, easy-to-install roofing systems that will improve the performance of Army roofing while reducing life-cycle costs.

Objective

The overall objective of this study is to (1) evaluate innovative roofing systems and materials to determine alternatives to BUR systems, (2) provide a means to improve Army-roof performance and reduce life-cycle costs, and (3) develop guide specifications for selected alternative systems.

The specific objective of this report is to document the review and evaluation investigation phase of this study, and to select alternative systems for further consideration and testing.

Approach

This study is being conducted in the following steps:

1. Survey of literature, manufacturer, and field applications to determine alternatives to BUR systems.

2. Selection of alternative systems for further consideration and testing.

3. Construction and instrumentation of the selected systems at Army installations.

4. Evaluation of test applications, including design, construction, and post-construction performance for 2 years.

5. Development of guide specification criteria.

This report documents Steps 1 and 2, above.

Mode of Technology Transfer

Criteria for application of alternative roofing systems will be included in TM 5-617, *Maintenance and Repair of Roofs,* and guide specifications for use in contracting application of the systems will be included in Real Property Maintenance Activities Guide Specification (RPMAGS) series 37000 and in Corps of Engineers Guide Specifications 07520 and 07540.

2 SURVEY OF ALTERNATIVE ROOFING SYSTEMS

General

Nontraditional roofing systems were evaluated to determine which were suitable for use in reroofing construction and versatile enough to be used in roofing maintenance and repair on the various building types found at Army installations. The systems identified as having the best potential were generally plastics or synthetic rubber elastomers. These materials are the products of recent developments in the plastics industry and may perform better than bituminous membranes. They offer many advantages over traditional BUR systems:[1]

1. Light weight–the various foam- and liquid-applied systems are extremely lightweight.

2. Adaptability–the systems are adaptable to almost any roof slope or substrate material, including architecturally prominent roofs.

3. High elasticity–elastomeric systems have elongation capabilities which can bridge cracks in the substrate and accommodate both thermally and structurally induced movement.

4. Good reflectivity–reflective-coated systems aid in reducing membrane temperature and heat gain within the interior of the structure.

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[1] W. J. Rossiter and R. G. Mathey, *Elastomeric Roofing: A Survey*, NBS Technical Note 972 (U.S. Department of Commerce, National Bureau of Standards, July 1978).

5. Low labor intensity—these systems generally require less effort to install than traditional BUR systems; application is cleaner, cooler, and requires smaller crews.

6. Easy repairability—reroofing or repair is relatively easy and sometimes can be completed without entirely removing the underlying system.

7. Easy insulation—these systems allow insulation to be readily added to existing buildings. In addition, foam systems are inherently insulating, and the insulated roof membrane assembly can often be placed over an existing roof.[2]

8. Compatibility—these systems allow the selection of material properties which are compatible with the local environment; e.g., a system may be selected that is resistant to a chemically hostile atmosphere.

9. Shortage immunity—most systems provide a certain degree of immunity to local asphalt shortages.

Materials

Some alternative roofing systems are proprietary compounds; however, several are now commercially available under generic chemical names such as ethylene propylene diene monomer (EPDM) or polyvinyl chloride (PVC) sheets. The following is a list of materials from which most of the more commonly used systems are manufactured.[3]

1. Acrylic polymers—good resistance to ultraviolet light (UV) and to weathering. Available as one-component liquid systems in a variety of colors.

2. Butyl rubber—resistant to ozone and weathering and has extremely low water vapor and gas permeability. Good resistance to corrosive chemicals, dilute mineral acids, and vegetable oils, but poor resistance to petroleum oils and gasoline. Available both as sheet and two-component liquid systems.

3. Chlorosulfonated polyethylene (commercially known as Hypalon*)—high resistance to ozone, heat, and weathering. Generally resistant to oils and chemical attack but will swell in aromatic and chlorinated solvents. May be formulated in a variety of stable colors. Available in sheet- or liquid-applied systems.

4. EPDM (ethylene propylene diene monomer)—properties are similar to butyl rubber, but exhibits better resistance to weathering and ozone. Not resistant to petroleum oils or gasoline. Available in sheet form, normally black color.

5. Neoprene—good resistance to petroleum oils, solvents, heat, and weathering. Available in liquid- or sheet-applied systems. Sheet systems come in a weathering grade (black) or a nonweathering grade (light colored). The latter must be protected by use of a coating (usually chlorosulfonated polyethylene).

6. PVC and vinyl—resistant to acids, alkalies, and many chemicals. Loss of plasticizers through aging and/or solar exposure can lead to embrittlement and shrinkage. Available as sheet- or liquid-applied systems.

7. Rubberized asphalt—embrittles at temperatures lower than asphalt and can maintain flexibility as low as -15°F (-26°C). Available as an emulsion (water soluble) or as a cutback (cures through evaporation of a petroleum solvent). May be applied hot or cold. Generally should not be used in an exposed situation. May be protected from solar degradation by aggregate surface or by placing insulation above the membrane in a protected-membrane system.

8. Silicone—semi-organic polymers which are resistant to high temperatures and are flexible at low temperatures. Good resistance to oxidation, ozone, and weathering; possess a higher water vapor permeability than other roofing elastomers. Available as one- or two-component liquid-applied systems. Tends to retain atmospheric dirt and may darken in time. Frequently used to protect polyurethane foam from weather degradation.[4]

[2] J. Keeton, R. Alumbaugh, and E. Humm, *Experimental Polyurethane Foam Roofing Systems,* Technical Note N-1450 (Civil Engineering Laboratory, Naval Construction Battalion Center, August 1976), ADA 031046.

[3] W. J. Rossiter and R. G. Mathey, *Elastomeric Roofing: A Survey,* NBS Technical Note 972 (U.S. Department of Commerce, National Bureau of Standards, July 1978).

*Hypalon is a registered trademark of E. I. Du Pont de Nemours and Co., Inc.

[4] *Protective Coatings for Polyurethane Foam Roofing Systems,* Technical Data Sheet 77-12 (Civil Engineering Laboratory, Naval Construction Battalion Center, July 1977).

9. Urethane (polyurethanes) synthetic polymers formed by a reaction between two chemical agents. Many different combinations are possible, and as a result, controlled variance of color, density, and other material properties is possible. Available as a foamed-in-place or liquid-applied system. (Foam is subject to weather degradation unless coated with a protective film.)[5]

Roofing Systems

This study evaluated three systems: sheet-applied, fluid-applied, and foamed-in-place. In addition, some hot- and cold-applied modified bituminous systems were considered. The advantages and disadvantages of these systems are as follows.

Sheet-Applied Systems (Advantages)

1. **Prefabricated.** The primary advantage of sheet-applied systems is the installation labor savings that result from prefabrication of the membrane. In addition, prefabrication enhances quality control because the main element of the roof system—the membrane—is manufactured under controlled conditions away from the construction site where rigorous control is not as feasible.

2. **Lightweight.** Most of the sheet-applied systems (except for the stone ballasted type) are much lighter in weight than traditional BUR systems.

3. **Easy to repair.** Sheet-applied systems are easy to repair; if the membrane is totally bonded, water will usually enter the building close to the point of damage or failure since there are no interply spaces to channel leaks. The membrane can then be patched with cement and small pieces of membrane material.

4. **Easy to flash and seal.** Sheet-applied systems are comparatively easy to flash and seal at projections with adhesives and elastomeric roofing accessories.

5. **Highly moisture permeable.** Sheet-applied systems display less tendency to blister since some single-ply systems have a fairly high permeability to moisture vapor and, in effect, "breathe." This feature makes the installation procedure less susceptible to inclement weather, and allows certain membranes to be used on wet decks.

6. **Easy to reroof.** Sheet-applied systems can be installed over an existing roof without completely removing the existing roof down to the original substrate.

7. **Reusable membrane.** It may be possible, depending on the condition of the sheet-applied membrane, to reuse loose-laid membranes. In this respect, loose-laid systems seem especially appropriate for temporary roofs where upward expansion of a facility is planned. In such cases, it may be possible to remove and reinstall the roof atop the new addition.

8. **Compound variety.** The material characteristics of sheet-applied systems may be selected to suit certain environmental or climatic conditions; e.g., materials may be selected especially for an industrial environment which requires flexibility at extremely low temperatures.

9. **Versatile and aesthetic.** Sheet-applied systems are versatile and aesthetically acceptable; e.g., buildings with architecturally prominent roofs can use some sheets to install gravel-free ballast, later coating the sheet with a protective film in a variety of colors.

10. **Extensible.** Elastomeric materials, when placed under stress, will elongate and return to their original shape upon removal of the stress. This insures that the membrane will bridge cracks in the substrate and will accommodate some structural movement.

11. **Easy to apply.** There are a variety of ways to assemble and place a sheet-applied membrane: (1) completely bond the membrane to the substrate using bitumen or elastomeric adhesives, (2) mechanically adhere the membrane with nails or fasteners, and (3) lay the membrane loosely, so there is no direct attachment to the substrate.

Sheet-Applied Systems (Disadvantages)

1. **Small safety factor.** Sheet-applied systems offer only a small safety factor since a single membrane layer will almost certainly allow any puncture or failure to cause leakage. Therefore, the success of these systems is critically dependent on competent workmanship which assures that the membrane is properly sealed.

2. **Lack of dimensional stability.** Some membrane materials are not dimensionally stable, and the resultant shrinkage may cause seam or flashing separations.

3. **Inadequate operational statistics.** While various sheet-applied systems have been used in Europe and

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[5] CPT J. D'Emidio, "Sprayed-Urethane for Roof Repairs," *The Military Engineer*, Vol 450 (July-August 1977), pp 244-246.

the United States for approximately 20 years, there has not been enough time to ascertain performance when compared with the 80-year history of BUR systems. Also, material changes occur frequently and a product purchased today may not resemble its counterpart purchased 5 to 10 years ago.

4. **Lack of performance and design criteria.** As a result of limited exposure and a wide variety of materials in use, there are no real standards by which to compare one sheet-applied system with another. The design parameters which must be controlled to insure proper performance are not well known.

Fluid-Applied Systems (Advantages)

1. **Easy to apply.** The membrane is applied as a liquid with either a spray gun or squeegee. Since the liquid flows to a limited degree, it can fill small cracks and cover irregularities in the new substrate or old roof surfaces. Liquids are especially suited for application to concrete and plywood decks.

2. **Self-flashing.** The homogeneous membrane is self-flashing and can be applied continuously from horizontal to vertical surfaces.

3. **Labor savings through smaller crews.** In general, fewer people are required to install a liquid-applied membrane than conventional BUR, and less time is required to complete the installation of a liquid-applied roof.

4. **Extensible.** The elastomeric materials used in fluid-applied systems are capable of elongating, then returning to their original shape. This quality accommodates limited structural movement, though not to the extent allowed by sheet-applied systems. Most elastomerics also offer low-temperature flexibility and will maintain their integrity at lower temperatures than bitumen-based materials.

5. **Easy to repair and maintain.** Fluid-applied membranes are generally repaired by reapplying the membrane with a spray gun or squeegee.

6. **Compound variety.** Various compounds and materials can be selected to meet such special requirements as compatibility with an underlying material or use in a chemically hostile atmosphere.

7. **Color variety.** Liquid-applied systems are often the best aesthetic choice, since their various compounds are easily colored with pigments. In addition, color keying each layer of a multilayered liquid-system roof can facilitate inspection and quality assurance.

Fluid-Applied Systems (Disadvantages)

1. **Limited substrate suitability.** Liquid systems are best suited for use only on concrete and plywood decks.

2. **Extensive substrate preparation.** The surface upon which the fluid is applied must be smooth, clean, and dry; failure is possible if the substrate is not properly prepared.

3. **Workmanship dependent.** Measurement of the wet thickness is difficult, and in the case of multicoat applications it can be difficult to assure complete coverage. However, this problem can be minimized by using different colored layers.

4. **Limited elongation.** While liquid systems exhibit some elastic properties, they generally cannot accommodate larger cracks nor tolerate structural movement as well as sheet-applied systems.

5. **Highly flammable solvent-based systems.** Some liquid-applied roofs present a substantial fire risk during installation; therefore, adequate safety and ventilation measures must be observed. There is also a risk of toxicity with some systems if installing crews are not protected from fumes and from contact with the components during application.

6. **Lack of long-term exposure performance data and design criteria.**

Foamed-in-Place Systems (Advantages)

1. **Insulation capability.** Since polyurethane foams are good insulators, they can be used to prevent excessive thermal movement in metal buildings by applying them on top of existing roof systems and on exterior surfaces.

2. **Easy to apply and repair.** Polyurethane foams are multicomponent systems that are applied with a special spray apparatus. Two layers (lifts) are recommended to insure an adequate seal. Damaged areas are repaired by removing failed sections and refoaming.

3. **Easy coverage.** Since the foam forms a homogeneous layer, it can be used to bridge cracks and irregularities in the substrate. The foamed-in-place system is also self-flashing and will seal readily at parapet walls and around projections.

4. **Lightweight**. Because foam systems are much lighter than conventional BUR systems, various densities and thicknesses of foam can be applied to meet many requirements for insulation, impact resistance, or roof traffic.

5. **Direct application to suitably prepared existing roof**. A weathered or damaged roof can, in effect, be stabilized by foam application.

Foamed-in-Place Systems (Disadvantages)

1. **Susceptibility to UV and weather degradation**. After curing, foamed-in-place systems must be coated with silicone rubber, butyl Hypalon, Hypalon mastic, catalized urethane, or other weather/ultraviolet resistant coatings and kept coated throughout the life of the roof to prevent UV- and/or weather-induced degradation.

2. **Low compressive and tensile strength**. A completed foam roof is subject to damage from hail and foot traffic; in some areas, birds and rodents are also capable of causing damage.

3. **Extensive preparation**. To insure proper adhesion, substrates must be thoroughly prepared to receive foamed-in-place systems. Such preparation includes removal of any loose or flaking section of an existing roof.

4. **Flammability**. Since foams are organic, they will burn; however, the full extent of the fire hazard they represent has not yet been determined. In particular, the direct application of foam over metal decks in habitable buildings is actively being researched and is considered an unacceptable use of foamed-in-place systems at this time. Foam roofs may be placed over metal decks if a suitable fire barrier is provided between the deck and the foam layer.

5. **Overspray**. Foam should either be applied when there is no wind or the work should be inclosed by canvas screens or other such systems, since the influence of wind during spraying can (1) make it difficult to control foam thickness, and (2) cause an overspray which can damage adjacent vehicles or buildings.

6. **Irregular surfaces**. Foaming systems do not generally provide an even roof surface. A somewhat uneven surface usually results which contains small depressions and other irregularities where water tends to pond after rain storms; to minimize this effect and other difficulties, such as mentioned in number 5 above, skilled foaming system operators are required.

Summary

Table 1 lists design and installation guidelines for the three major alternative systems reviewed by this investigation.

It is apparent that there are alternatives to traditional methods of roofing that may be suitable for use on Army facilities. However, it is equally apparent that no one system is the best for all applications, making the design/decision process complex. In addition, since elastomeric materials have been used for a relatively short time in the United States, predicting the performance of elastomeric roofing systems is difficult. Frequent changes in material composition of the roofing systems also add to the difficulty of predicting system performance.

3 RESULTS OF SITE VISITS

General

Site visits were conducted to determine if sheet- and fluid-applied and foamed-in-place systems are performing satisfactorily enough to merit full-scale field tests at Army installations. The site visits also provided a means of (1) evaluating the practicality and acceptability of alternative system construction procedures, and (2) field testing construction monitoring techniques. Both previously constructed roofs and roofs under construction were surveyed (see Appendices A and B).

Approach

In-Place Roofing Systems

Seven single-ply, two foamed-in-place, and six liquid-applied roofs in Illinois, New York, Pennsylvania, New Jersey, Tennessee, Louisiana, and Texas were inspected. The general condition of the roofs was determined and photographs made of significant features and distresses. In each case, the owner/user, manufacturer's representative, roofing contractor, or another individual(s) familiar with the history of the roof since its construction was interviewed. The overall performance of the system at the given site was then evaluated. If performance was unsatisfactory, the probable causes were analyzed to determine if modifying construction details, or other methods, could improve performance. Systems were then selected for consideration for use at Army installations. This selection was based on performance alone, independent of cost considerations, although comparative construction cost information

Table 1
Design and Installation Criteria*

Criteria	Sheet Applied**	Liquid Applied+	Foamed in Place++
Fastening adhesion	•Loose laid •Mechanically fastened •Bonded (adhered)	•Homogeneous bond (spray or squeegee)	•Homogeneous bond (spray)
Laps/splices	•Heat fused •Solvent welded •Solvent and tape (clean lap is essential: overheating or excessive solvent may lead to failure)	•No joints (homogeneous membrane)	•No joints (homogeneous material)
Perimeter	•PVC clad metal •Adhesive bond •Heat fused (all components must be well anchored)	•Self sealing; allow for expansion and differential movement	•Self sealing; allow for expansion and differential movement
Repair of damage	•Use approved patching materials and cements (see manufacturer)	•Clean and recoat with same or compatible compound (see manufacturer)	•Remove damaged foam, dry thoroughly, and refoam
Prefabricated accessories	•PVC clad flashings at curbs for use with PVC. •Adhesives or heat fused at horizontal flanges; counterflash with same materials at edges (see manufacturer)		•Self-flashing, but allow for expansion and/or movement which could cause cracks
Ballast	•Loose laid systems require ballast; with IRMA (PMR) system, place ballast over insulation (stone or concrete pavers)	•Some materials may be suitable for IRMA (PMR) system. Place ballast over insulation. See manufacturer	•No ballast
Coatings	•Some systems use UV-resistant coating on unballasted systems; e.g., Hypalon over neoprene (see manufacturer)	•Some systems are multi-coat. (See manufacturer)	•Coating is essential; should be applied as soon as possible after foaming and replenished throughout life of roof
Bitumen *compatibility*	•PVC-no asphalt, coal tar pitch, plastic cement, or certain wood treatments •EPDM-no coal tar pitch or plastic cement •Butyl-no petroleum oils	•See manufacturer (*many different* compounds and formulations are available)	•Generally compatible with asphaltic and coal tar materials; however, adhesion is best on older bituminous materials

Table 1 (cont'd)
Design and Installation Criteria*

Criteria	Sheet Applied**	Liquid Applied+	Foamed in Place++
Installation constraints and substrate	•Low-wind conditions •Clean substrate, no sharp projections •Cold temperature and excessive solvent retard weld time •Moisture permissible with some permeable materials •Clean lap joint essential, especially with EPDM	•Clean, dry substrate •Low-wind conditions for spray applied materials •No foot traffic until membrane is cured •Apply second coat in a direction perpendicular to first	•Clean, dry substrate •Low-wind conditions •Remove flakes, scales; preparation of damaged areas •Two lifts recommended to insure seal
Susceptibility to damage	•Visual discoloration from overheating could be a potential failure point •Cigarette burns must be avoided (also flammable solvent) •Easily damaged by loaded wheeled vehicles	•Gouging or thin coat could lead to premature failure of membrane	•Susceptible to impact damage (hail, tools, etc.) •Possible rodent and bird damage
Use over existing roof	•Most systems may be used over properly prepared existing (see manufacturer) roof; if wet insulation is present, membrane must be vapor permeable to allow drying •If ballast is used, check structural capacity of deck	•Some materials may be suitable. (Manufacturers specify some materials as suitable for use over existing roofs. However, field observations did not support this. See Appendix A.)	•Foam is ideal for retrofit application; substrate must be dry and suitably prepared. (Adds substantial insulation value.)
Slope	•Fully adhered and mechanically fastened systems may be used at greater slopes than loose-laid systems	•No real slope restrictions; most can be applied from horizontal to vertical	•No real slope restrictions; foam can be sprayed on surfaces from horizontal through vertical

*Buyers Guide to Single-Ply Systems," *Roofing, Siding, and Insulation Magazine*, Vol 5 (November 1977), p 67.

**W. J. Rossiter and R. G. Mathey, *Elastomeric Roofing: A Survey*, National Bureau of Standards Technical Note 972 (U.S. Department of Commerce, National Bureau of Standards, July 1978); K. Duchon and J. Parker, *Use and Market Opportunities for Plastics in the Roofing Industry* (SPE 33rd Annual Technical Conference [May 1975]).

+W. J. Rossiter.

++B. V. Jones, *Laboratory and Field Investigation of New Materials for Roof Construction*, REC-ERC-76-4 (U.S. Bureau of Reclamation, Engineering and Research Center PB259635, April 1976).

was collected for each of the three systems being investigated.

Roofing Systems Under Construction

The construction of Navy experimental roofs (see Appendix B) was monitored to collect general data and to evaluate ideas for future Army tests. The construction operations were monitored full time using stop-action photography to provide a condensed, permanent record of the entire construction process. Observers also maintained a daily log of construction activities and related events, and recorded still photographs of the construction as it progressed. Samples of materials used in the roofs were collected, and the roofs' plans and specifications were analyzed to determine if the construction was proceeding according to their requirements.

Summary of Findings

It was determined that (1) most of the single-ply and foamed-in-place roofing systems performed reasonably well, and (2) two of the six liquid-applied roofing systems observed performed satisfactorily (see Appendix A). Based on these findings single-ply and foamed-in-place roofing systems were selected for further consideration through full-scale field applications. Further evaluation is necessary before liquid-applied roofing systems can be selected for use in Army field tests.

The monitoring of the Navy experimental roofs indicated that special provisions for quality control and assurance are required to insure that the test roofs are constructed correctly (see Appendix B).

4 CONCLUSIONS

1. Site surveys confirmed the potential of sheet-applied and foamed-in-place roofing systems as viable alternatives to conventional BUR systems. These systems are generally easier to apply, and some weigh less than conventional BUR. In addition, the foamed-in-place system offers a significant increase in insulation efficiency over conventional BUR.

2. Liquid-applied systems, although versatile, aesthetic, and easily adapted to architectural roofs, have performed unreliably in some cases.

CITED REFERENCES

"Buyer's Guide to Single-Ply Systems," *Roofing, Siding, and Insulation Magazine,* Vol 5 (November 1977).

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APPENDIX A: SUMMARY OF SITE VISITS TO OBSERVE NEW ROOFING SYSTEMS

Background

In addition to a literature review, actual site visits and interviews with owners and/or applicators were conducted to achieve an accurate picture of each sheet-applied, fluid-applied, or foamed-in-place system under consideration. Emphasis was placed on finding roofs of each type that had been in service for at least 2 or 3 years, since any serious performance problems should have surfaced by then.

Sheet-Applied Roofing Systems

Sample 1

The lobby and restaurant at Chicago's O'Hare International Airport (Figure A1) are covered by a sheet-applied roofing system. Information and comments on performance were provided by O'Hare's Supervisor of Skilled Maintenance.

1. System: Carlisle Tire and Rubber Company loose-laid, color-coated, butyl-rubber Sure Seal Universal Roofing System.

2. Age: Installed 1962-63.

3. General appearance: Circular roof, approximately 190 ft (57.9 m) in diameter—"deep dish" shape. There is a 3 ft (0.9144 m) wide ring around the perimeter of the roof which drops down 3 ft (0.9144 m) and then slopes inward for another 25 ft (7.63 m) of height (see Figure A1). The surface of the roof is generally smooth, with only a few projections, including AC units, vents, and an access area.

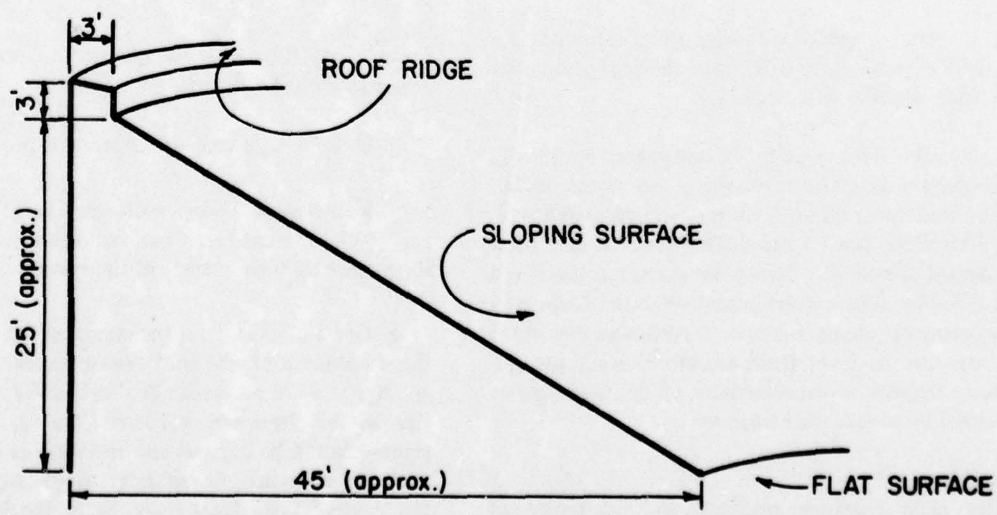

Figure A1. General appearance of O'Hare lobby and restaurant roof.

4. Observable problems:

a. The insulation is slipping down the slope, causing a wave-like effect under the rubber membrane.

b. Dirt, clumps of weeds, and water are collected at the bottom of the slope.

c. The area around the kitchen vent is covered with black grease (approximately a 50 sq ft [15.24 m^2] area).

5. Maintenance:

a. The edges of the roof are sealed with flashing and caulked. Once a year, the entire metal ring should be recaulked where needed; i.e., anywhere the flashing has pulled away or the caulking has cracked.

b. Every 5 to 8 years, the entire roof should be covered with a coat of sealant (liquid).

c. Foot traffic should be kept to a minimum once the roof is completed, and measures taken to prevent sharp objects from tearing the membrane, e.g., spiked heels, tripod legs, etc.

d. The seam cement should be checked occasionally. Cement should not be picked at or disturbed in any way.

e. The roof should be kept as clean as possible, i.e., free of rocks, dirt, weeds, and other foreign material.

f. Slate or wood walkways along the roof edge should not be used. A fiberboard material should be used where a walkway is necessary.

6. Overall: This system is considered extremely satisfactory if properly maintained. No cracks or failures caused by structural movement were observed, even after more than 15 years of service. The insulation has slipped appreciably during the years, but this could be avoided by adhering the insulation to the deck, then loose-laying the membrane over it. Although the insulation was wet by leaks from uncaulked areas and improperly finished roof projections, all failures could be prevented by proper maintenance.

Sample 2

The main entrance vestibule and bookstore of Thayer Hall at the U.S. Military Academy, West Point, NY, are covered with a sheet-applied roofing system. Information and comments on performance were provided by the Facilities Engineer's Supervisor of Metal and Machine Shops and former Chief, Engineering Division.

1. System: Gates Gacoflex Sheet Neoprene Roofing System over Urethane Insulation Board. Color: Black.

2. Age: Installed November 1975.

3. General appearance: There is a single roof over the vestibule which is approximately 32 sq ft (9.76 m^2). The bookstore is covered by three roofs 16 sq ft (4.88 m^2); each roof has a slight slope toward a single drain, and parapet walls. The surfaces of the roofs are smooth.

4. Observable problems:

a. Vestibule roof:

(1) The west half of the roof has large ripples (6 in. [151.4 mm] long × 1 in. [25.4 mm] high) running across the laps for the entire length of each lap. The laps are heavily coated with a black rubberized compound which shows signs of deterioration, e.g., cracks, pinholes, and dryness. The neoprene sheet appears to be in good condition, except at the laps.

(2) The east half of the roof–both sheets and laps–is smooth; however, the black rubberized compound applied over the laps contains small cracks and pinholes.

(3) Ripples at the seams cause water to pond at the west half of the roof.

b. Bookstore roof–no observable problems.

5. Maintenance: None performed as of 22 December 1978. Manufacturer has not been contacted for instruction on maintenance of the system.

6. Overall: Except for the seams on the west half of the vestibule roof, the roof system appears to be very good. There are no cracks or visible signs of deterioration in the sheet material itself. The laps containing ripples should be cut out and replaced with new sheet material, applying the adhesive to the laps only and *not* coating the edge or surface of the lap with the black rubberized material.

Sample 3

Building 753 at the U.S. Military Academy, West Point, NY, is also covered by a sheet-applied roofing system. Information and comments on performance were provided by the Facilities Engineer's Supervisor of Metal and Machine Shops and former Chief, Engineering Division.

1. System: Gates Gacoflex Sheet Neoprene Roofing System over an old sandblasted copper roof. Color: Green.

2. Age: Installed 1973.

3. General appearance: There are three separate roofs on this building, measuring 65 X 208 ft (19.8 X 63.5 m), 75 X 80 ft (22.9 X 24.4 m), and 80 X 80 ft (24.4 X 24.4 m). The first roof is over section (class) rooms, the second over a lecture hall, and the third over a chemistry laboratory. Each roof is pitched (approximately 3 on 12) from the ridge to the outer walls, except for half the roof over the lecture hall, which is almost flat. Parapet walls surround each roof. The surfaces of the roofs are smooth except for the ridges. The standing seams on the old copper roof were flattened out, and the new roof applied over vent pipes, ventilators, skylights, access hatches, and the dome and pipe supports for the walkway, all of which include base flashings, side walls, etc. Laps are approximately 3 in. (76.2 mm) wide and are tight. There are no cracks or visible signs of deterioration. The finish coating is green and it appears that it has been broadcasted with a nonslip substance.

4. Observable problems: One blister about the size of a softball is on the east wall just below the vent on the chemistry lab roof, and several small blisters are at the bottom edge of the dome of the lecture hall roof.

5. Maintenance: None performed since roof system was installed nor is any required as of this date (27 December 1978).

6. Overall: This roof system should be adequate for use on many of the U.S. Military Academy's problem roofs. This system has also been used for reroofing other buildings and family quarters at the U.S. Military Academy.

Sample 4

The Alcoa Aluminum Plant in Alcoa, TN, has a single-ply roof over a portion of its installation. Information and comments on performance were provided by the President of MM Systems, which installed the roof.

1. System: MM Systems' Carbofol Single-Ply Roofing System; used on a tearoff project.

2. Age: Under construction–will be completed within 1 month.

3. General appearance: The roof was large and rectangular–approximately 250 X 1000 ft (75 X 300 m). There were scattered projections across the roof surface, including large AC units, several vents, and four circular hatchways. The system was bitumen bonded, a process in which a thin layer of bitumen is spread across the insulation surface and the Carbofol membrane imbedded into it to firmly adhere the membrane to the roof. (The insulation was mechanically adhered.) The Carbofol was in 5-ft (1.5-m) widths, with an overlap of 2 in. (5 mm) which was hot-air-welded to the next strip of membrane. The flashing was prefabricated, incorporating sheet metal strips and similar lengths of Carbofol. The sheet metal was attached to the roof edge and the Carbofol strip flapped back over the edge to be hot-air-welded to the roof membrane. Carbofol pieces were cut to fit snugly around the circular hatchways and hot-air-welded to the roofing membrane. A final coat of fluid-applied elastomeric coating (reflective) was applied directly over the Carbofol membrane.

4. Observable problems: Since the system is still under construction, no problems are apparent yet.

5. Maintenance: Maintenance involves finding the point(s) of failure, cutting a suitably sized patch of Carbofol membrane, and hot-air-welding the patch to the roofing membrane over the failure point.

6. Overall: This system appears to be reliable, but has two major drawbacks: (a) it has not been used very long in the United States (this is only the second installation in the country), and (b) MM Systems is the only source of the Carbofol membrane. MM Systems imports membrane materials from Germany.

Sample 5

The New Orleans International Airport has a single-ply roof over a long area of concourse. Information and comments on performance were provided by the President of Elastomeric Supply & Service Co., Inc.

1. System: Water Guidance System's Plyroof Single-Ply Roofing System. Plasticized PVC sheets over an existing BUR loosely laid with ballast.

2. Age: Installed in 1978.

3. General appearance: The covered area is a long, rectangular concourse, with several vents and AC units scattered across the surface. The sheets (Plyroof PVC 32) are overlapped by 2 in. (5 mm), solvent-welded, and caulked down the seams. Standard sheet metal flashing is used with the PVC sheets, and a final layer of rounded river-washed stone is used for ballast.

4. Observable problems: The concourse had no leaks, and overall, was in very good shape. There were small areas (e.g., around doorways) where some of the stone ballast had been pushed away to reveal the PVC membrane below, but since the PVC formulation contained both plasticizers and UV-resistant chemicals, this was supposedly no problem. The exposed membrane showed no signs of weathering.

5. Maintenance: No maintenance had been required as of January 1979. If leaks do occur, repair will involve finding the point(s) of failure and solvent-welding a patch of PVC membrane over the spot.

6. Overall: This appears to be a very reliable and effective roofing system. The installation procedure is relatively simple, quick, and safe. There is also the added benefit of the multi-source status of PVC membranes, which will allow for competitive bidding on the same system.

Sample 6

A middle school gymnasium in New Orleans, LA, is covered by a single-ply roof. Information and comments on the performance of this system were provided by a sales representative of Koppers, Co.

1. System: Koppers Multipurpose Membrane with aluminum finish (new construction).

2. Age: Installed in 1977.

3. General appearance: The roof was barrel-vaulted, about 20 ft (6 m) wide, spanning about 50 ft (15 m), and arching 10 ft (3 m) at its highest point. The roof had four vent projections. The KMM was in 2.5-ft (.75-m) strips arching across the barrel-vaulted roof, and embedded in a layer of bitumen. The strips of KMM were welded together where they overlapped. Conventional sheet metal flashing was used.

4. Observable problems: The roof leaked around the edges where it was connected to the flashing. It had not been determined whether the leaks were caused by faulty initial workmanship or by the membrane pulling away from the flashing.

5. Maintenance: Re-caulking of the flashing/membrane seam might improve the watertightness of the roof. New patches of KMM can be welded over any holes or failure points that may occur in the membrane itself.

6. Overall: The KMM has a variety of drawbacks: (1) the membrane has a single source (Koppers), (2) although used in Europe for several years, the membrane has had a relatively short exposure time in the United States, and (3) because it is a layer of different materials, the membrane can be a problem when uniform contraction and expansion are required. The membrane itself could expand and contract at different rates and eventually delaminate. [NOTE: Occurrence of this last aspect has not been documented, but the potential problem was pointed out by a source knowledgeable in the single-ply roofing field.]

Sample 7

The Travis County Courthouse in Austin, TX, has a single-ply roof. Information and comments concerning performance were provided by the courthouse's general maintenance engineer.

1. System: Gates Engineering "Gacoflex" Single-Ply Roofing System–sheets of neoprene, imbedded with surface granules laid over the original built-up roof (urethane board insulation).

2. Age: Installed in 1978.

3. General appearance: The roof was basically rectangular, covering approximately 3000 sq ft (270 m^2), with a complex network of AC units, pipe, and ductwork running across its surface. Up to 4 in. (10 cm) of water was standing on the roof's surface, being deepest in the center, and tapering to an almost dry surface around the perimeters (where the roof drains were located). This problem was the result of the architectural design, however, not of the Gacoflex membrane itself. Gates Engineering adhesive was used to bond the neoprene sheets to the insulation, and an adhesive was used to bond the overlapping neoprene sheets together. The roofing granules were then added. Coordinating Gacoflex flashings were used.

4. Observable problems: The roof leaked, but this problem must be attributed partially to the architec-

tural design, which allowed water to pond for long periods of time (and at some depth) on the roof. The maintenance engineer theorized that the water was getting in above the flashing on the vent and AC projections.

5. Maintenance: No maintenance had been required for the membrane itself. Caulking was reapplied around the roof projections in an attempt to make the roof watertight. As of February 1979, plans were under way to install a roof drain in the center of the roof where the water ponding was deepest.

6. Overall: Even though this roof exhibited some problems, the overall Gacoflex system seems to be reliable. Neoprene has had widespread, successful exposure in the United States and can be procured from several sources. The neoprene can also be coated with Hypalon to further protect it from UV and chemical attack (at the U.S. latitudes, the Hypalon is not *required*), and to provide a color coat.

Fluid-Applied Roofing Systems

Sample 1

The fluid-applied roof at Kishwaukee College in Malta, IL, was surveyed; information regarding the roof was obtained from the Building Superintendent for the college.

1. System: Applied Polymers of America, Inc., Ureloid Single Component–Liquid Waterproofing Membrane over a concrete deck.

2. Age: Installed 1971.

3. General appearance: The roof is approximately 20 by 30 ft (6.1 by 9.14 m) and doubles as a walkway. Off of this roof area is a boiler room (also approximately 20 by 30 ft [6.1 by 9.14 m]) which is open to the sky and uses the liquid-applied waterproofing as a floor (this area also acts as a roof for lower levels of the building). The boiler room has several projections through the floor, including rectangular concrete slabs which support large equipment. The membrane is a light tan color.

4. Observable problems:

a. In the walkway area, wherever the membrane meets a wall, the membrane is cracked and leaking along the edges. There appear to be no expansion joints, and as building movement occurs, the fluid-applied membrane cracks and splits. There are no cracks in the center of the area.

b. In the boiler room, the membrane appears to have been extended up the wall approximately 4 in. (101 mm), and no cracks have occurred. No cracks were observed in the concrete slabs the equipment is resting on, nor in the membrane which extends 4 in. (101 mm) up the side of the slab.

5. Maintenance:

a. Proper initial application is essential. Coverage must be uniform and adequate. Edges and abutments must be sealed properly.

b. When cracks and splits do occur, the same material or a compatible sealant should be used to seal the failure. Adequate expansion joints must be provided since the membrane is not elastic enough to span large areas.

6. Overall: This roof is probably not the best example of a fluid-applied roof; apparently it was not installed correctly. Its history has been one of "catch-up" maintenance.

Sample 2

The second fluid-applied roof was a cooling tower observed at a site in Philadelphia, PA. Information regarding the roof was obtained from an applicator for Applied Polymers of America, Inc.

1. System: Applied Polymers of America, Inc., Ureloid Single Component Liquid Waterproofing Membrane over a concrete deck.

2. Age: Installed 1971.

3. General appearance: The roof serves as both a roof for lower stories and as a floor for the cooling tower of the building. The cooling tower takes up an area of approximately 30 by 70 ft (9.14 by 21.3 m), and is about 20 ft (6.1 m) high. (See Figure A2.)

The surface of the fluid-applied roof is smooth, although the application was very uneven—there are spots where the elastomeric membrane is thin and spots where it is very thick, with clumps ranging in size from approximately 1/8 to 1 in. (3.18 to 25.4 mm). There are several projections through the membrane, including numerous redwood 4 X 4 support members and approximately four drainage areas.

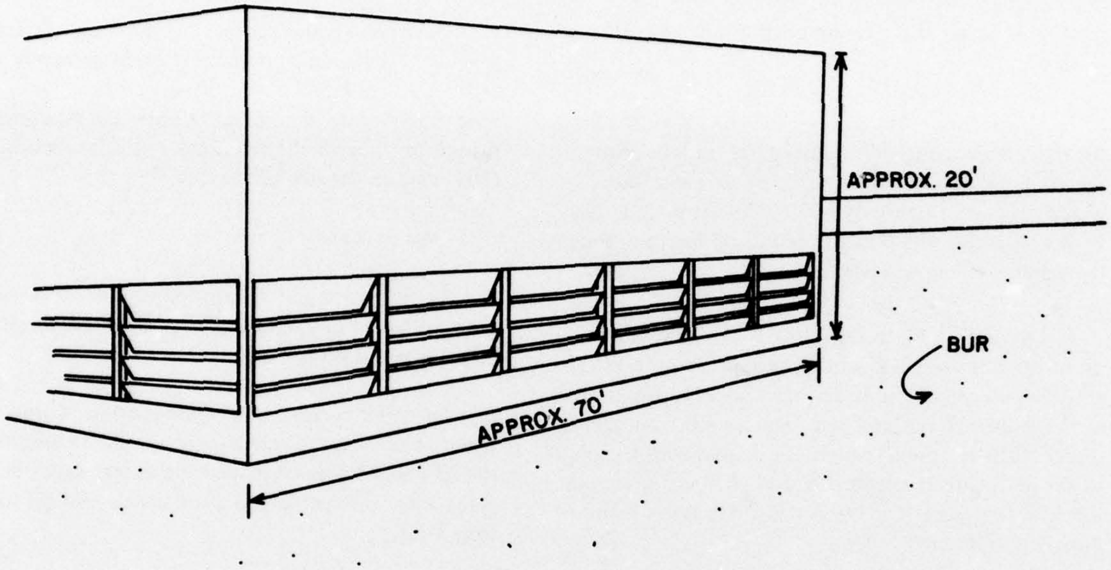

Figure A2. Liquid-applied roofing system–Sample 2.

4. Observable problems: The only noticeable problem is the uneven application of the fluid-applied membrane, but this has not caused mechanical failure of the roof. Overall, the roof has performed satisfactorily.

5. Maintenance:

a. The applicator indicated that the moderating influence of water from the cooling tower was the only reason this roof has worked as well as it has. When the cooling tower is in operation, water collects on the roof to a depth of approximately 1 ft (.3048 m); correspondingly, continuous drainage keeps this level constant. The membrane is thus protected from extreme temperature changes, foot traffic, and UV light. However, even with this continuous exposure to water, the applicator noted that the membrane has lost most, if not all, of its original elasticity and flexibility and is becoming almost brittle.

b. The membrane has been extended approximately 1-1/2 to 2 ft (.4572 to .61 m) along the sides on all the 4 X 4 redwood support members and along the perimeter of the cooling tower. This has prevented the standing water from leaking through the membrane. The membrane has been patched in places using the same liquid material.

6. Overall: This is a unique application of the fluid-applied roofing system and one to which it is well suited. For a standard roofing job, however, its use is not recommended, since failure is inevitable for any plastic membrane exposed to UV light for any length of time.

Sample 3

The third fluid-applied roof was observed in Holmsdel, NJ, at the Charles of the Ritz complex. Information regarding the roof was obtained from the Building Superintendent.

1. System: Applied Polymers of America, Inc., Ureloid Single Component Liquid Waterproofing Membrane over an original BUR system.

2. Age: Installed 1971.

3. General appearance: The roof is large, flat, and approximately 80 by 160 ft (24.4 by 48.8 m). The surface of the membrane is fairly smooth, but the coating

is very uneven. There are several projections, including access areas, AC units, vents, and drains. The coating has an aluminum (metallic) sheen.

4. Observable problems:

a. The membrane has numerous splits, cracks, and blisters over its surface.

b. The coating is not uniform across the substrate.

c. In several places, the coating was not extended up the side of abutting walls or projections.

5. Maintenance:

a. This roof has been a failure from the start, but the failure is not entirely the fault of the product. The original roof was a three-ply BUR system with wet insulation. When this roof failed, a two-ply BUR system was applied, but the roof was not allowed to dry. When this second roof failed, Applied Polymer's fluid-applied system was used to cover the roof. Unfortunately, the membrane did not have the elasticity to cope with the increasing number of blisters and cracks developing because of trapped water vapor pressure. As a result, the membrane is cracked and split. Plans are now under way to replace the entire roof once again.

b. The metallic tint of the coating was intended to reflect the summer sun's rays and to aid in energy conservation. However, any energy savings which might have been effected have been offset by the roof's mechanical failure.

6. Overall: Poor workmanship has caused the multiple roof failures suffered by this building. At no time was the roof allowed to dry out completely, directly contributing to the consecutive failures. The fluid-applied roof–the latest application–was not capable of sealing the cracks and splits of the BUR systems beneath it, resulting in overall roof failure. The Superintendent indicated that, even considering the poor existing conditions of the BUR systems, the fluid-applied roof did not live up to expectations, and should not be recommended for use except as a reflective coating for energy conservation.

Sample 4

The fourth fluid-applied system observed was the walk-on roof at Building No. 609, the Gas Turbine Lab and Public Comfort Station, U.S. Military Academy, West Point, NY. Information regarding the roof was obtained from the Facilities Engineer's former Chief, Engineering Division.

1. System: Sika Chemical Corporation, Sika Flexible System (Epoxy).

2. Age: Installed 1976.

3. General appearance: The walk-on roof is approximately 32 × 100 ft (9.45 × 30.5 m) and doubles as a roof and walk-on deck. Approximately one-third of the area is used for multiple purposes, e.g., bus stop, observation deck for visitors, and a rest area. The rest area is covered by a shelter-type roof supported by columns, with no side walls. The building itself was built into the side of a hill with three walls exposed, and one completely covered by earth. All floors, including the walk-on roof, are below road level. Access is from the sidewalk which runs parallel to the covered wall. An opening was cut through the parapet wall and metal stairs were installed for the pedestrians, since the roof level is 16 in. (40.6 mm) below the sidewalk (see Figure A3).

The surface of the walk-on roof is smooth; there are several projections, such as columns and vents for plumbing. The center area was designed for use as a bus stop. Benches have flat boards attached to the bottom of the legs, and backs of benches are secured to the columns. The walk-on roof is used by many visitors to the U.S. Military Academy; the building affords a commanding view of the Hudson River and surrounding areas. The base flashing is of the same construction and materials as the walk-on roof with the exposed edge protected by metal counter flashings.

4. Observable problems:

a. The base flashing is loose along the northeast wall (see Figure A3).

b. In two locations, the aggregate is either worn off or the binder has dried before the aggregate was applied (see Figure A3).

c. Leaves and twigs from nearby trees have accumulated along the northwest wall, causing stains.

5. Maintenance: None performed as of 23 December 1978. Even though the flashing is loose, it presents no problem since the counter flashing protects the exposed opening. Bare or worn spots should be recoated

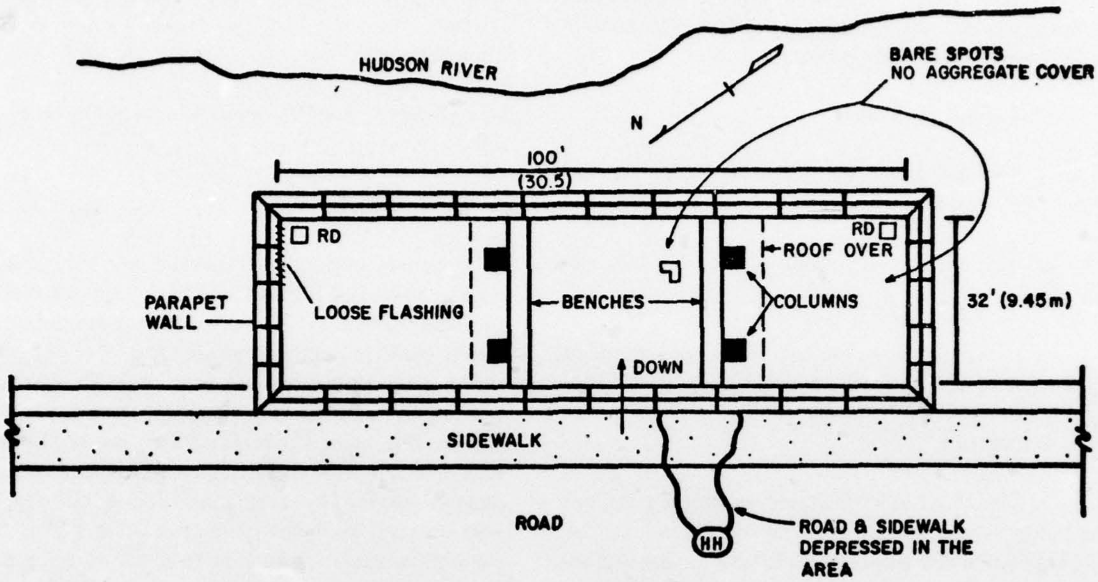

Figure A3. Roof on Building No. 609, U.S. Military Academy.

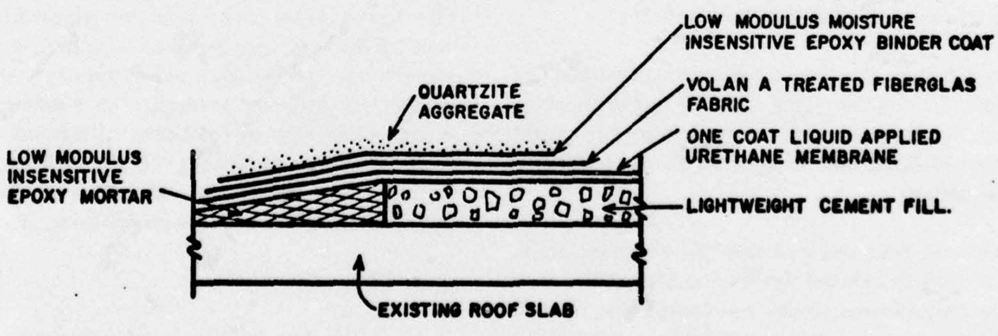

Figure A4. Cross section of Building No. 609.

with binder and broadcasted with quartzite aggregate while wet.

6. Overall: This system looks very promising; no cracks or failures have been caused by structural movement. However, before this system was applied, the old BUR and concrete fill was removed down to the structural roof slab and New Perlite Lightweight reinforced concrete fill was combined with a moisture-insensitive low-modulus epoxy fill to provide a base for the new system. See Figure A4.

Water is seeping inside the building near the steps leading to the walk-on roof; the sidewalk and part of the road are also depressed in this same area.

The roof should be periodically cleaned of debris to prevent clogging roof drains and/or staining the roof.

Sample 5

The fifth fluid-applied system observed was the traffic-type deck on Building No. 753, Bartlett Hall, U.S. Military Academy, West Point, NY. Information regarding the roof was obtained from the Facilities Engineer's Supervisor of Metal and Machine Shop and former Chief, Engineer Division.

1. System: Foch Brothers Division Carboline Company, Polytok Deck Coating 131.

2. Age: Installed June 1976.

3. General appearance: The traffic top deck is L-shaped, approximately 10 ft (3.05 m) wide, with a combined length of 161 ft (49.1 m), and doubles as a roof and walkway. The walk is smooth, separated by a lower landing and steps. See Figure A5.

The walkway is situated between two buildings and is sloped to a common drain at the foot of the stairs. There are no projections; joints are sealed.

4. Observable problems: Transverse cracks are noticeable in the upper walks, and the traffic top at the landing has broken up into small pieces.

5. Maintenance: None has been performed as of 22 December 1978. Expansion and other joints should be properly sealed to keep water from seeping in between the concrete deck and traffic top.

6. Overall: This traffic top was probably not applied correctly at its initial installation.

Sample 6

The sixth fluid-applied system investigated was on Building No. 663, Field House, U.S. Military Academy, West Point, NY; however, it was not observed. Information regarding the roof was obtained from the Facilities Engineer's Supervisor of Metal and Machine Shop and former Chief, Engineer Division.

1. System: Carboline Special Products Division: Roof-Flex Color Coat.

2. Age: Installed in 1974; replaced in 1978 with a completely new roofing system.

This system, when applied to an existing smooth surface BUR on an incline of 22-1/2°, did not live up to the manufacturer's expectations. (The manufacturer's representative was present during the application.) Before 1 year elapsed, the coating ruptured when the old BUR underneath started to check and crack. In the summer of 1978, this system, along with the old BUR, was removed and replaced with asphalt strip shingles. Roof surface was approximately 800 sq ft (7200 m^2).

Foamed-in-Place Roofing Systems

Sample 1

The first foamed-in-place roof was observed at a warehouse building in Chicago, IL. Information regarding the roof was obtained from an applicator for the Dow Corning Corporation.

1. System: Foamed-in-place plus coating. The foam was a rigid, sprayed-on polyurethane, 2 in. (50.8 mm) thick. The waterproofing and protective coating was

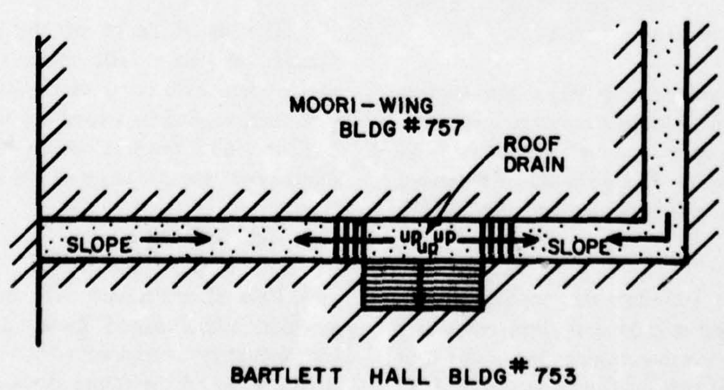

Figure A5. Roof of Building No. 753, U.S. Military Academy.

Dow Corning Silicone Rubber, 20 mils (0.51 mm) thick. Small stone granules imbedded in coat of silicone can be optionally used with this system.

2. Age: Installed 1973.

3. General appearance: Rectangular, sloped roof with longitudinal center ridge, approximately 30 by 200 ft (9.14 by 61 m); slope is approximately 30°. The foam was sprayed over a metal deck and the deck's ridges are still visible. Although the surface is rough and gravelly, the coating of foam and silicone appears uniform over the roof surface. There is one vent projection.

4. Observable problems:

a. There are several holes and torn areas where rocks or other sharp objects have chipped off portions of the coating and penetrated the foam. Where the foam has been exposed to the elements, oxidation has begun, turning the area rust-orange. There are also several small broken spots.

b. On the sides of some of the ridges of the decking, the silicone coating was not applied in sufficient amounts and has worn off. Oxidation of the foam is also evident on the ridges.

c. In some areas, the foam does not completely cover the decking edge.

5. Maintenance:

a. The roof should be kept as clean as possible since material such as rocks or heavy branches can damage it.

b. Wherever a hole or chipped spot has occurred, the area should be refoamed and recoated.

c. Competent workmanship when the roof is first applied is important; adequate coverage is essential to prevent future worn spots, and proper sealing around the edges is also necessary. Foam should be extended around and under the metal decking, then covered with silicone.

d. Dow Corning (through the applicator) will guarantee the roof against leaks and chips for 3 or 5 years, and will perform annual inspections of the roof and repair any damage that may have occurred. After the warranty has expired, yearly preventive maintenance is important to assure the long life of the roof.

e. Birds and rodents have been known to attack the foam, causing considerable damage (although that had not happened to this roof). There are now special coatings on the market that will repel birds, etc., and prevent this type of damage.

6. Overall: This appears to be a good system with high insulation qualities. The applicator stated that the urethane foam and silicone coating (without roof granules) have passed the UL 790 Fire Test.

Sample 2

The second foamed-in-place roof was observed at the Naval Reserve Center in Clifton, NJ. Information regarding the roof was obtained from a user of the building and other sources as cited below.

1. System: Foamed-in-place plus coating; these roofs are experimental, and a variety of products were tested:

System 1: catalyzed silicone rubber coating (General Electric Company)

System 2: moisture-curing silicone (Dow Corning Corporation)

System 3: catalyzed butyl Hypalon (U.S. Polymeric)

System 4: Hypalon mastic (Foster Division, Amchem Products, Inc.)

System 5: catalyzed butyl Hypalon (United Coatings).

The metal decks of the buildings were first cleaned, then an asphalt primer (for better adhesion) was applied. Two coats of urethane foam (CPR-485) were then applied to a total thickness of not less than 2-1/2 in. (63.5 mm). A variety of coatings were then applied over specific areas of the roof (see Figure A6).

2. Age: Installed 1974.

3. General appearance: The buildings are two rectangular, prefabricated metal structures, connected approximately at midpoint by a small concrete block structure, called the Boiler House. The North Building

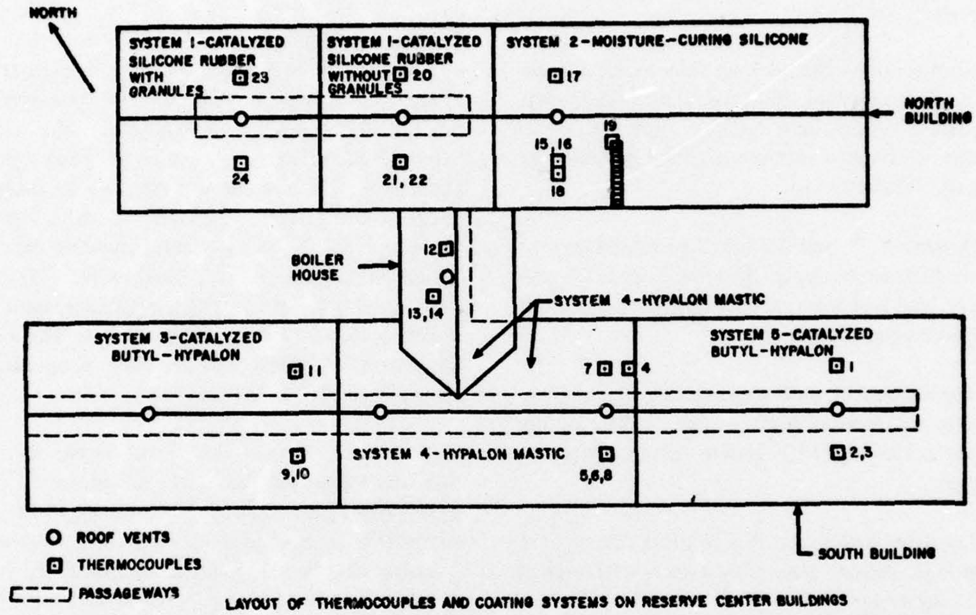

Figure A6. Layout of thermocoupler and coating system on Naval Reserve Center buildings.

is 162 by 40 ft (49.4 by 12.2 m); the South Building is 203 by 40 ft (61.9 by 12.2 m). All roofs are sloped approximately 30° off a center longitudinal ridge. There are several vent projections from the roofs, plus an anchored walkway connecting with a metal access ladder.

4. Observable problems:

a. There are occasional small holes where rocks, hail, or other sharp objects have chipped parts of the coating and penetrated the foam. In these areas, oxidation of the foam has occurred as it came in contact with the elements, turning the foam rust-orange.

b. Birds have attacked small areas, causing some damage to the foam.

c. In several places, the foam seems thicker than the 2-1/2 in. (63.5 mm) prescribed. Some of these spots may be patch areas, however.

5. Other maintenance and installation information:[6]

a. A polyurethane foam (PUF) roof system can be expected to reduce fuel usage by as much as 53 percent compared to metal roofs with little or no insulation.

b. White coatings can reduce daytime temperatures on the top surface of roof systems by 10° to 30°F (5.5 to 16.7°C) compared to medium-gray coatings.

c. Gravel stops can cause low areas which can allow water to pond, and therefore should not be used on roofs of metal buildings that are to have PUF roof systems.

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[6] J. Keeton, R. Alumbaugh, and E. Humm, *Experimental Polyurethane Foam Roofing Systems*, Technical Note N-1450 (Civil Engineering Laboratory, Naval Construction Battalion Center, August 1976), ADA 031046.

d. The butyl-Hypalon and Hypalon mastic coating systems were damaged by hailstones. Such damage requires the roof to be recoated with hail-resistant coatings as soon as possible to prevent degradation of the PUF system.

e. Roof sections coated with silicone elastomers were not damaged by hail. Indications are that an elastomeric coating system used on PUF roof systems is hail-resistant if it has a minimum tensile strength of 300 psi (2.06×10^5 Pa).

f. Systems 1, 2, and 5 applied easily. Systems 3 and 4 were difficult to apply. Systems 1, 2, and 5 performed very well and were comparable until System 5 was damaged during a hailstorm.

g. Application of roofing granules in the wet top coat appears to improve performance of the coating systems and makes the PUF system more resistant to bird damage.

h. Localized failures in PUF roofing systems are easily repaired; repairs generally restore the original integrity of the system.

i. The excellent insulating characteristic of PUF systems is indicated by the stabilization of the base of foam and attic temperatures at about $70° \pm 10°F$ (21.1 $\pm$ 5.6°C) year round.

j. Failure to remove all old coatings from the roof deck prior to foaming does not disbond the foam.

k. When vapor-permeable coatings are specified for PUF systems, the silicones of Systems 1 and 2 are recommended. When vapor-impermeable coatings are required, the catalyzed butyl-Hypalon of System 5 is recommended if hailstones are not likely to be a problem.

l. A minimum thickness of 2-1/2 in. (63.5 mm) of PUF is recommended to stabilize interior temperatures and to meet Department of Defense criteria for energy conservation on roofs with no existing insulation.

6. Overall: The polyurethane foam roofing system—with specific coatings—has proven to be a reliable and effective roofing system with high insulation qualities. The PUF roofs have not leaked, and the portions coated with the silicone elastomerics have not suffered any appreciable external damage. However, PUF systems appear to be inappropriate for completely flat roofs since water collection can eventually damage the foam. (Minimum slope of 1/4 in. [.63 cm] per ft [.3 m] is required.)

Composite-Applied Systems

The first composite applied system used at the U.S. Military Academy, West Point, NY, was applied over asphalt paving blocks on exterior porches at the Enlisted Men's Barracks more than 20 years ago. Several years later, the system was applied to problem sun decks at the Hospital, Building No. 606; Gymnasium, Building No. 727; Bartlett Hall, Building No. 753; and a walkway at the Library, Building No. 757. Information regarding the composite-applied system used on Building No. 727 was obtained from the Engineer's Supervisor of Metal and Machine Shop and former Chief, Engineering Division.

1. System: Dex-O-Tex Weatherwear as manufactured by Crossfield Products Corporation. The system is loose-laid and consists of multi-layered troweled application composed principally of neoprene rubber, dehydrating powder, pigments, vulcanizers, and aggregates. It is 3/16 to 1/4 in. (4.75 to 6.35 mm) thick and is applied over a patented slip-sheet, thus forming a monolithic roof and flashing.

2. Age: Installed 1962.

3. General appearance: The roof/deck is approximately 72×118 ft (22×36 m) and doubles as a roof and sun deck. (The original roof/deck construction was quarry tile, with little slope toward roof drains.) The roof/deck is smooth and surrounded by parapet walls; there are no projections. The roof surface has a few small puddles of water.

4. Observable problems: The top coating is cracked and peeling. There are a few blisters and some cracks in trowel coats of neoprene and aggregate composition.

5. Maintenance: Although this roof/deck could be repaired by local masons and painters, both the Supervisor of Metal and Machine Shops and former Chief, Engineering Division agree it would be best to have it repaired by a qualified Dex-O-Tex contractor.

A floor-type sander should be used to entirely remove the surface coating. The deck covering should be examined for deep cracks; any cracks should be cut out and patched with a mixture of liquid neoprene and powder. The patches should then be sanded smooth,

and a grout coat applied over the entire deck. A roller should be used to apply coats of surface coating. Every 6 to 8 years, the surface should be recoated with Dex-O-Tex special sealer (this can be done by local painters).

The covering should be examined for cracks, particularly at the bottom of the base flashing, the only place where this system is fastened to the roof/deck.

Sharp objects such as spiked heels, furniture, or equipment with small legs or tubing should not be permitted on the roof/deck.

Snow can be removed with snow shovels that do *not* have sharp edges or corners to gouge the surface. Ice choppers should not be used.

Normal deposits of dirt and grime can be cleaned by hosing or mopping with clean water. Ground-in grease spots should be scrubbed with a warm water and detergent solution and rinsed with clean water.

6. Overall: A very good roofing system when properly maintained. No cracks or failures have been caused by structural movement. The cracks and surface-coating peeling could have been prevented had the surface of the deck been properly cleaned before it was recoated (about 9 years ago).

APPENDIX B: NAVAL EXPERIMENTAL ROOFS PROJECT

Description of Test

The U.S. Navy has undertaken a program of constructing six different types of roofing systems for experimental and evaluation purposes. These roofs are being constructed at a Naval facility on the East coast of CONUS, at a location subject to high winds and severe weather. Four cold-applied systems, a hot-applied asphalt BUR system with insulation above the membrane, and one standard hot-applied BUR membrane with insulation below and embedded gravel above are being constructed. Five of the systems being evaluated are proprietary. The standard roof is to provide a basis for comparison. All of the roofs are being installed within a 1-year period.

Cold-Applied Systems

1. GAF Mineral Shield Roofing, a product of GAF Corporation, Building Materials Group, 140 West 51st Street, New York, NY 10020. Figure B1 shows planned experimental roof.

2. Sure-Seal Waterproofing System, a product of Carlisle Tire & Rubber Company, Division of Carlisle Corporation, Carlisle, PA 17013. Figure B2 shows planned experimental roof.

3. Energy Efficient Rated Roofing System (EERRS), a product of EERRS, Inc., 644 West 24th Street, Tempe, AZ 85282. Figure B3 shows planned experimental roof.

4. Gacoflex Liquid Urethane Rubber, a product of GACO-Western, Inc., P.O. Box 88698, Tukwila Station, Seattle, WA 98188. Figure B4 shows planned experimental roof.

Hot-Applied Systems

1. Inverted Roof Membrane Assembly (IRMA), a product of Dow Chemical Company, Midland, MI. Figure B5 shows planned experimental roof.

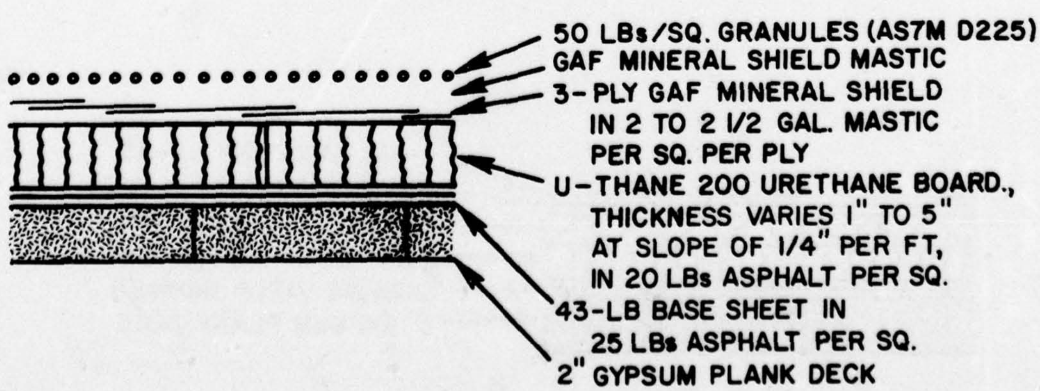

Figure B1. GAF Mineral Shield roof.

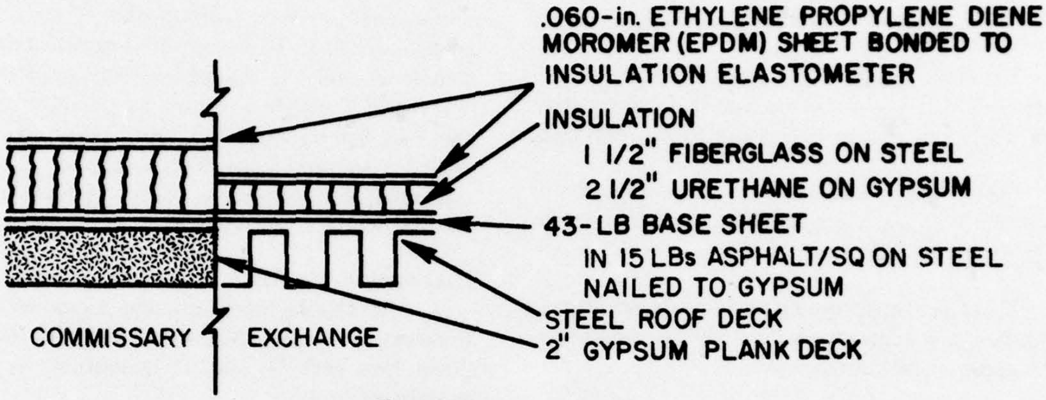

Figure B2. Sure-Seal roof.

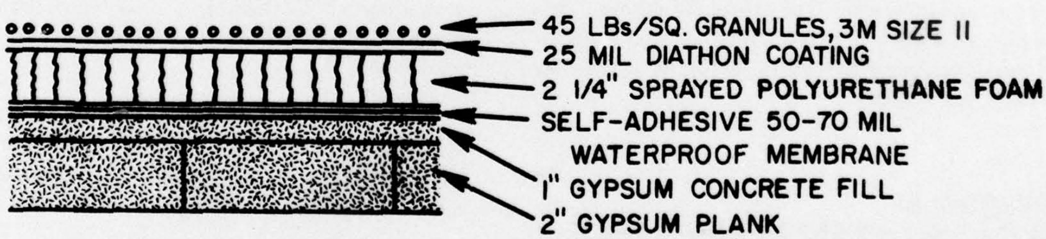

Figure B3. Energy Efficient Rated Roofing System (EERRS) roof.

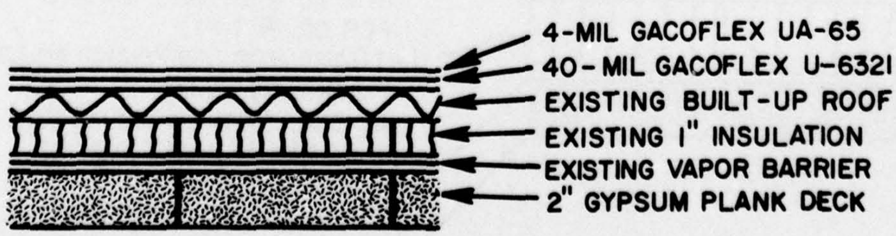

Figure B4. Gacoflex roof.

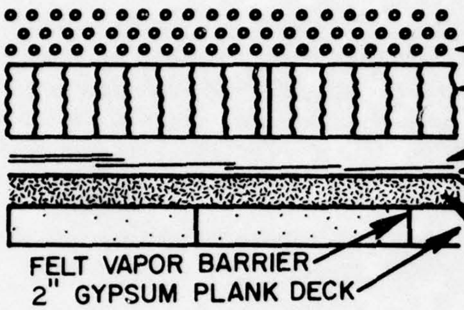

Figure B5. Insulated Roofing Membrane Assembly (IRMA) roof.

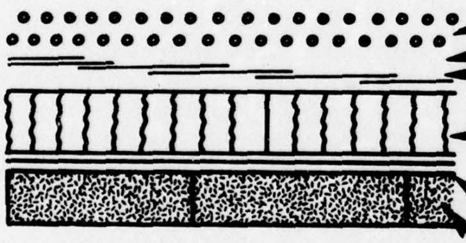

Figure B6. Built-up roof.

2. Standard three-ply built-up roof. Figure B6 shows planned experimental roof.

CERL Participation

CERL is observing and recording the installation of the roofs and evaluating their performance over a 2-year period. Observation methods include fulltime inspection of construction by a roof construction expert; a narrative description of construction; photographs; stop action motion pictures; contract documentation such as plans and specifications; and materials samples.

Periodic surveys are planned during the following 2 years to determine the effect of aging on the moisture content of each roof. Simultaneously with each moisture survey, a thorough visual inspection will be made to observe any obvious deterioration.

APPENDIX C: GUIDE TO MANUFACTURERS OF NEW ROOFING SYSTEMS

Background

Although only three basic new roofing systems are being considered in this study—sheet applied, fluid applied, and foamed in place—a variety of manufacturers produce the materials that make up each system. This appendix summarizes some of the systems that are produced by commercial manufacturers. The information is broken down into the product's general use, materials, and the positive qualities of the specific manufacturer's product. The source of all information, including the qualities of each product, is the specific manufacturer's catalog for the system.

Sheet-Applied (or Single-Ply) Roofing Systems

Carlisle Tire and Rubber Company

Carlisle offers several single-ply systems, the elastomer being either ethylene propylene diene monomer (EPDM) or neoprene (synthetic rubber). The main difference among the systems is the bonding technique used.

Universal Design A.

1. General use: Carlisle Sure-Seal Elastomeric Membrane is secured to the substrate by bonding with adhesive and supplemental fasteners.

2. Materials: the elastomeric membrane can be made of either EPDM or neoprene.

3. Qualities:

a. Sure-Seal EPDM sheet membrane demonstrates superior ozone resistance and remains elastic through wide temperature fluctuations, is impermeable, resistant to UV and weathering in general, and is ideal for exposed areas.

b. Sure-Seal neoprene sheet membrane is impermeable, self-extinguishing (i.e., does not support combustion), and ozone resistant.

Universal Design B.

1. General use: Carlisle Sure-Seal Elastomeric Sheets are laid loose over approved insulation (also loose-laid) or suitable support and secured only at the perimeter and around penetrations. Design B uses a ballast of river-washed stone, pavers, or water distributed evenly over the membrane to hold the membrane down.

2. Materials: the elastomeric membrane can be made of either EPDM or neoprene.

3. Qualities: identical to Universal Design A.

Universal Design C.

1. General use: Carlisle Sure-Seal Elastomeric Membrane Sheeting is installed under Dow Styrofoam RM* as specified by Amspec, Dow's roofing subsidiary. Installation is performed by an Amspec-approved roofing contractor. This is a Protected Membrane Roofing (PMR) system. Different bonding methods include:

a. Membrane bonded to substrate with insulation adhered to upper surface of membrane and ballasted.

b. Membrane loose-laid over substrate with insulation adhered to upper surface of membrane and ballasted.

c. Membrane loose-laid over substrate with approved insulation loose-laid and ballasted (sometimes used in temporary applications where all roofing materials are to be salvaged and used).

2. Materials: the elastomeric membrane can be made of either EPDM or neoprene.

Carlisle Sure-Seal Elastomeric Flashing and Elastoform Flashing.

1. General use: the flashing accessories that Carlisle specifies.

2. Materials: Carlisle Sure-Seal Flashing is made of a dense, highly inert synthetic rubber compound.

3. Qualities: Carlisle Sure-Seal Flashing has exceptional resistance to outdoor exposure, extreme temperature changes, and all natural elements. It does not propagate flame. Sure-Seal Flashing is a rugged, elastic material which readily adapts to irregular shapes and surfaces, and is outstandingly resistant to transmission of water and vapor.

Gates Engineering Company (Gacoflex)

General Use. Gacoflex N-3S is an elastomeric neoprene sheet that will conform to a variety of shapes and substrates (concrete, wood, plywood, insulation, most metals, new or old roofs, etc.). The neoprene

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*Trademark.

sheet is topcoated with two coats of Hypalon, which comes in more than 14 standard colors plus numerous customized color tones. Gacoflex adhesive and caulking are used to seal seams and flashings.

Materials. Gacoflex N-35 is an elastomeric neoprene sheet; Hypalon is an elastomeric topcoat that is impervious to UV radiation, chemical degradation, and weathering. Gate's Contour Flash–an elastomeric flashing system–is specified for use with the roofing system.

Qualities.

1. Versatile–allows freedom of design.

2. Strong and durable–remains flexible at temperatures as low as -50°F (-45.6°C).

3. A variety of surface finishes–aesthetically pleasing and retains quality appearance longer.

4. Tough, resilient–withstands the effects of snow, ice, sleet, hail, and rain.

5. Wind-uplift danger almost completely eliminated.

6. Chemically resistant.

7. Waterproof.

8. Withstands normal footwear traffic.

9. Bridges cracks and withstands structural movements equal to or better than comparable roofing systems.

Water Guidance Systems, Inc.

Plyroof PVC 32.

1. General use: to waterproof roof decks having slopes of less than 2 in. per foot (167 mm per meter) on substrates of wood, metal, or concrete; uses a ballast of rounded stone in the loose-laid system.

2. Materials: homogeneous sheet of plasticized, flexible PVC.

3. Qualities:

a. Weatherproof.

b. Stabilized against UV radiation.

c. Resistant to most atmospheric pollutants.

d. Waterproof but vapor-permeable.

e. Rot-proof.

f. Easily installed.

g. High tensile strength.

h. Eliminates roof expansion joints.

Plyroof PVC 32R and Plyroof PVC 45R (heavier).

1. General use: to waterproof roof decks having slopes of less than 2 in. per foot (167 mm per meter), on substrates of wood, metal, or concrete; uses a ballast of rounded stone in the loose-laid system.

2. Materials: two homogeneous sheets of plasticized, flexible PVC laminated to each side of a nylon reinforcing screen.

3. Qualities:

a. Excellent puncture resistance.

b. Excellent tear resistance.

c. Weatherproof.

d. Stabilized against UV radiation.

e. Waterproof but vapor-permeable.

f. High tensile strength.

g. Excellent chemical resistance.

h. Easily installed.

i. High breaking strength.

Plyroof EP 30 and Plyroof EP 45 (heavier).

1. General use: to waterproof roof decks having slopes of less than 2 in. per foot (167 mm per meter). It is applied directly to substrates of wood, metal, or concrete, and uses a ballast of rounded stone in the loosely laid systems. May be used for fully adhered smooth systems on wood and concrete roof decks and insulated metal decks.

2. Materials: EPDM synthetic rubber reinforced with nylon fabric.

3. Qualities:

a. Weatherproof.

b. Chemically resistant.

c. Excellent temperature range.

d. Excellent impermeability.

e. High puncture resistance.

Plyflash Laminate.

1. General use: to be used as a typical sheet metal flashing in order to provide continuity to the Plyroof PVC loose-laid roofing system.

2. Materials: galvanized sheet metal laminated with PVC sheeting on one side and protective primer on the opposite side.

3. Qualities:

a. Corrosion resistant.

b. Easily formed.

U. S. M. Weather-Shield Systems Company

Smooth Braas Rhenofol CV-48 System.

1. General use: The membrane is designed to resist exposure to weathering; it is spot-attached to the deck to provide the required wind uplift resistance without use of surfacing ballast.

2. Materials: The membrane is Rhenofol CV-48 plasticized PVC, reinforced with one layer of synthetic fiber fabric for increased dimensional stability and tensile strength.

3. Qualities:

a. Low dead load–lightweight, since there is no heavy ballast.

b. Wind uplift forces are transferred to the structural deck.

c. Attachment to the structure at roof perimeter and roof openings is greatly simplified.

d. Installed in almost any weather.

e. Applicable on almost any slope.

f. Formulated to resist rotting, swelling, mildew, molds, UV degradation, tears, heat, snow, hail, water, salt air, cold, industrial fumes, ashes, oxidation, and any combination of these factors.

g. Approved by Factory Mutual for various applications.

h. Specifically recommended for: light decks to minimize deflection; reroofing on steel deck and insulated deck; roofs with slope exceeding 1 in. per ft (25 mm per m); high wind areas; roofs where anchorage at the perimeter is difficult or costly; and roofs where ballast is not applicable.

Ballasted Braas Rhenofol C-34 System.

1. General use: A loosely laid roofing membrane covers the whole roof assembly, and the membrane is attached to the structure at the roof edges, the roof openings, and at the adjacent roofing system. The surfacing ballast (10 lbs per sq ft [48 kg/m^2]) provides the proper resistance to wind uplift.

2. Materials: Rhenofol C-34 is plasticized polyvinylchloride with ultraviolet absorber and antioxidant.

3. Qualities:

a. Loosely laid installation allows for maximum freedom of movement.

b. Rhenofol membrane provides an absolute waterproof weather shield.

c. Ventilated installation eliminates moisture build-up.

d. Installation is simple and rapid in almost any weather.

e. Membrane can be prefabricated into large segments off site.

f. Can be installed over damp substrates.

g. Formulated to resist a large range of weathering forces.

h. Good for dead-level roofs–eliminates the need for sloping roof structure or tapering insulation.

i. Installation cost compares favorably with that of conventional roofing systems.

j. Specifically recommended for: any flat roof with less than 1 in./ft (25mm/m) slope, especially on roofs with high thermal performance; on roofs with high inside humidity conditions; and for reroofing on noncombustible decks.

NOTE: For normal construction, the Rhenofol C-34 provides a most economical solution; however, for more complicated roofs with many openings and projections, the Rhenofol CV-35 *reinforced* membrane may be more economical because of the simplified attachments. Rhenofol CV-35 is also ballasted and retains all the qualities of the CV-34 system.

Dynamit Nobel of America, Inc.

Trocal Roofing System.

1. General use: The Trocal membrane is designed for roofs having less than 1 in./ft (25 mm/m) slope, and consists of a stretchable sheet, loosely laid with ballast, that covers the entire roof from edge to edge.

2. Materials: The Trocal membrane is a plasticized, UV-treated sheet of polyvinylchloride.

3. Qualities:

a. Resists rotting, warping, swelling, deterioration caused by heat and sunlight, tears and punctures, extreme heat, ice, snow, running water, standing water, salt water, common exhaust fumes, extreme cold, thermal shock caused by radical temperature fluctuations, incinerator ashes, and furnace residues.

b. Resists cracking and leaking caused by substructure movement; Trocal can "give" more than 200 percent.

c. Vapor-permeable; breathes, which eliminates blistering of the roof surface.

d. Can be laid on icy, snowy, wet, or humid surfaces, and can be used on dead-flat roofs where ponding of water is a possibility; remains watertight.

e. Can be prefabricated off-site in sections.

f. Does not require expansion joints.

g. Requires little or no maintenance.

h. Safe to install—no hot roofing hazards, fumes, tar, or asphalt.

i. Only roofing system guaranteed against leaks caused by structural movement or cracking.

j. No tearoff of old roof required—Trocal can be laid directly over previous roof.

k. Vapor barrier (if required), insulation, and Trocal membrane are all loosely laid, with solvent used to make the Trocal membrane a homogeneous skin fastened only at roof edges and projections. This provides great freedom of movement between the building and the roof. The whole assembly is then ballasted with washed river-bottom gravel to resist displacement by wind and water.

l. Savings of up to 25 percent on insulation; lower cooling loads; retention of existing insulation value on renovation projects.

Koppers Company

Stonemat Standard Grade Multipurpose Membrane (KMM) Roofing System.

1. General use: KMM is a versatile, prefabricated sheet of cold-applied waterproofing material. Koppers Stonemat Roofing Specification No. 610 consists of a protective layer of loose stone over a fiberglass mat applied to standard grade KMM. The KMM membrane forms a waterproof roofing system through the use of joint heat fusion, a process whereby all continuous joints are affixed together to develop a monolithic waterproof membrane. This KMM system is attached to its substrate at the perimeter and at all through-system projections. Recommended for roof slopes up to 1 in. per foot (83 mm per meter).

2. Materials: In its standard form, KMM is a five-layer laminate composed of a thick, flexible plastic core protected on each surface by a layer of modified bitumen and an outer coating of polyethylene film. The stonemat topping consists of a layer of 1 in. (25.4 mm) fiberglass batting laid as a mat on the KMM over which is applied 1200 lb/sq ft (58.5 kg/m^2) of specification aggregate; if smooth gravel is available, the fiberglass batt layer can be eliminated.

3. Qualities:

a. Impervious to air, water vapor, and gases.

b. Factory-assured quality control.

c. Good elongation properties.

d. Clean, quick, easy, and effective installation.

e. Practically eliminates blistering and splitting.

f. Easy modification and repair.

Bituminous Aggregate Topping (BAT) KMM Roofing System.

1. General use: Koppers BAT Roofing Specification No. 620 consists of a protective layer of Koppers Bituminous Aggregate Topping applied to KMM. Recommended for roof slopes up to 1-1/2 in. per foot (125 mm per meter).

2. Materials: In its standard form, KMM is a five-layer laminate composed of a thick, flexible plastic core protected on each surface by a layer of modified bitumen and an outer coating of polyethylene film. This is then coated by BAT.

3. Qualities: identical to Stonemat KMM roofing system.

Aluminum KMM Roofing System.

1. General use: Koppers Aluminum Roofing Specification No. 630 consists of an aluminum-clad KMM membrane applied to its substrate in a full bed of KMM adhesive. Because of the aluminum cladding, this roofing system requires no additional topping except in areas of roof traffic. The aluminum KMM membrane forms a waterproof roofing system through the use of joint heat fusion, a process whereby all contiguous joints are affixed together to develop a monolithic waterproof membrane. KMM aluminum may be used on any slope up to vertical. It is recommended that areas subject to traffic be protected with walking treads. Ponded water collects atmospheric pollutants which may result in tarnishing the aluminum and therefore should be avoided.

2. Materials: aluminum KMM is a five-layer laminate composed of a plastic core protected on each side by modified bitumen, with a top surface of heavy, embossed aluminum foil and a bottom layer of polyethylene film.

3. Qualities: identical to Stonemat KMM roofing system with an additional feature--the reflective aluminum coating of Aluminum KMM is energy-efficient.

MM Systems Corporation (Carbofol)

General Use. The Carbofol membrane is a single-ply sheet that can be applied over an existing roof or used in new roof construction. The method of application varies:

1. Mechanically bonded: metal anchor straps fasten the membrane to the deck; perimeter edges and penetrations are welded to seal and flashed. One coat of reflective coating is required.

2. Bonded with bitumen: the Carbofol membrane is fully embedded in a coat of hot bitumen; all seams are welded, and edges are flashed; one coat of reflective coating is required.

3. Invert applied: the Carbofol membrane is mechanically adhered or welded at the perimeter and penetrations, insulation is laid over the membrane (as specified by Dow Chemical Company, manufacturer of Styrofoam RM Insulation) and ballasted; flashing is applied.

4. Loosely laid with ballast: insulation is loose-laid, then Carbofol membrane loose-laid over it and adhered at perimeters and penetrations; ballasted 10 to 12 lb/sq ft (49 to 58 kg/m^2); flashing is applied.

Materials. The Carbofol membrane is a thermoplastic, with primary ingredients of Lucobit, bitumen, anthracite coal dust, and ethylene. The base surface of the membrane is covered with a plastic fiber.

Qualities.

1. Weatherproof.

2. High puncture resistance.

3. Can be installed in rain or snow in temperatures as low as -13°F (-25°C).

4. Easily repaired.

5. Resistant to solvent containing paints, lacquers, and agglutinants in cases of brief exposure.

6. Compatible with asphaltic bitumen (but not with any tar-based bitumens).

7. Variety of application procedures.

8. Carbofol membrane is not resistant to the following substances: Benzine, Benzol (Benzene) petroleum, organic solvents, greases, oils (lubricating oils, diesel oils, oleiferous wood preservatives), tar-containing materials (tarred boards, bonding compounds on a tar

base), acids, and lyes of a high concentration and temperature.

Fluid-Applied Roofing Systems

3M Company

General Use. Scotch-Clad Brand Deck Coating System R is a fluid-applied roofing membrane with or without an exposed color aggregate surface. The coating system is designed for use on concrete, plywood, asphaltic concrete, masonry, metal surfaces, and polyurethane insulating foam to provide a continuous, seamless, waterproof, durable membrane which is resistant to weather aging. The membrane must be applied to hard, smooth, clean substrates. Concrete surfaces must be cured by an approved curing agent or water curing process. Concrete must be completely cured, dry, and uncontaminated to the extent that ordinary alkaline cleaners, muriatic acid, or light sandblasting will properly prepare the surface. Once installed, it is extremely difficult to remove the coating. Application of roof coating can only be made where adequate ventilation can be provided, as breathing of fumes and contact with skin is dangerous. Roof coatings are highly flammable until all solvents have dried out.

Materials. Scotch-Clad Brand Deck Coating System R is comprised of one-component, moisture-curing, polyurethane elastomers.

Qualities.

1. Variety of substrate possibilities.

2. Durable.

3. Weather-resistant.

4. Wide range of colors–red, green, beige, black, gray, and custom colors; exposed aggregate available in a variety of colors.

5. Flat or granular finish.

6. Abrasion resistant.

7. Tear resistant.

8. Good elongation and adhesion properties.

9. Bridges joints and cracks–stays tough yet flexible to maintain a waterproof seal.

10. System rated class A on noncombustible substrate.

Carlisle Tire and Rubber Company

General Use. Universal Design D forms a continuous, seamless elastomeric coating through the use of Carlisle Sure-Seal Liquiseal liquid membrane. Liquiseal can be used as the elastomeric membrane in Design C (PMR system), over poured concrete and other approved decks, or it can be used without insulation under pavers, concrete slabs, outdoor carpetings, or other approved surfacings. This liquid-applied elastomeric membrane cannot withstand exposure to UV light, and therefore must be covered either with insulation (as in Universal Design C) or with substantial ballast.

Materials. Liquiseal is a two-component, one-coat material which cures to a seamless elastomeric coating. It can be applied by squeegee, roller, or spray.

Qualities (when protected from UV light by coating or covering):

1. Long-lasting.

2. Weatherproof.

3. Lightweight (when coated, as opposed to ballasted).

4. Easily applied.

5. Prefab flashing accessories.

Gates Engineering Company (Gacoflex)

General Use. When Gates Gacoflex Elastomeric Liquid Roofing System is applied to recommended roof decks and air cured, the result is an homogeneous, waterproof, impermeable roof that is continuous and flexible.

Materials. The Gacoflex liquid-applied system consists of two coats of neoprene, followed by two coats of Hypalon synthetic rubber, with each coat being allowed to air-cure dry.

Qualities.

1. Versatile–suitable for application over exterior grade plywood and structural concrete.

2. Durable–remains flexible at very low temperatures.

3. Waterproof.

4. High chemical resistance.

5. Lightweight, yet strong and dependable.

6. Freedom of design–conforms to a variety of shapes.

7. Aesthetically pleasing–available in a dozen basic colors plus innumerable color tone variations.

8. Experience–Gates Engineering has specialized in the formulation and production of quality elastomers since 1938. Experience includes not only some of the oldest neoprene-Hypalon installations, but the most extensive continuous use of elastomers in roofing.

9. Underwriters Laboratory (UL) listed–The Gacoflex liquid-applied neoprene-Hypalon roofing system is listed by UL as a Class A system on noncombustible decks and a Class C system on plywood decks.

10. Compatible flashing system–Gates Contour Flash is available for use with the liquid-applied roofing system.

Foamed-in-Place Roofing Systems
General Electric Company

General Use. The General Electric Silicone roofing system includes two coatings of spray-applied silicone over foamed-in-place polyurethane insulation. Application is fast and economical. System components are easy to handle and require less labor than conventional BUR systems. While material costs may be slightly higher than other systems, ***installed*** costs are competitive with these systems. The silicone roofing system is a high-quality system and is easily installed.

1. Surface preparation–all direct, loose gravel, and other contaminants are removed from the roofing substrate. Any blisters or breaks in existing membrane are repaired.

2. Foam application–once the surface is properly prepared and dry, a monolithic, uniform layer of urethane foam at a specified density is sprayed in place.

3. Silicone coating–the silicone coating is applied in two applications. A silicone base coat of 10 mils (0.25 mm) is spray-applied to the freshly applied foam surface. A silicone top coat of 10 mils (0.25 mm) is then applied over the cured first coat. An optional layer of General Electric Granusil roofing granules can then be spray-applied to the silicone top coat before it cures. The roofing granules help conceal any joints and surface imperfections, resist streaking and discoloring, and provide added resistance to traffic.

Materials. The General Electric spray-applied roofing system consists of a seamless blanket of lightweight rigid urethane foam coated with silicone rubber.

Qualities.

1. No seams–monolithic system eliminates fishmouth wrinkles where felts overlap (a frequent cause of leaks in BUR systems).

2. Lightweight–this roofing system is lighter than conventional BUR systems and weighs approximately 1/2 lb/sq ft (2.5 kg/m^2) (about one-tenth the weight of a standard BUR system with gravel). For remedial applications, the system does not make severe structural demands on existing roof supports. Its light weight makes it well suited to new construction when long spans and few supports are involved.

3. Insulates–a 1-in. (25.4-mm) thickness of urethane foam coated with silicone rubber can help reduce heating and air conditioning costs as compared with an equivalent thickness of BUR systems. In new construction, lower initial investment in heating and air conditioning equipment may be possible.

4. Long life–silicone rubber coating is a stable, protective coating that provides outstanding protection from heat, cold, and oxidation. At recommended thickness it shields urethane foam from the sun's ultraviolet light. Unaffected by temperatures from -65 to 300°F (-54 to 150°C), the silicone rubber will not creep in high summer heat or embrittle at low winter temperatures.

5. Water repellent/vapor permeable–repels water and inhibits adhesion of snow and ice. Allows escape of some water vapor trapped inside substrate, helping to prevent blistering and loss of insulation efficiency due to moisture saturation.

6. Easily applied–can be directly applied over old roof. Eliminates costly roof removal, operational shutdown, and exposure to weather. Provides extra insulation and reduces thermal shock to original substrate.

7. Simple to maintain–system can be easily and permanently repaired with ready-to-use General Electric Silicone Construction Sealant. Leaks caused by mechanical damage are easy to locate because water

does not move laterally through closed-cell urethane foam as it does between the plies of BUR systems.

8. Nonpolluting–the spray-applied silicone roofing system, unlike BUR systems, does not smoke or require asphalt kettles and eliminates air pollution problems. In addition, the system conforms to existing solvent emission codes.

9. Code approvals–when installed in compliance with applicable restrictions and specifications, this General Electric roof system may meet Factory Mutual requirements when installed on an existing BUR system on a Class 1 deck. The system also has been approved by such code agencies as the International Conference of Building Officials (ICBO).

10. Applicators–the General Electric Silicone roofing system is available only through the General Electric Company.

3M Company

General Use. 3M's foamed-in-place roofing system combines advantages of a long-lasting, weatherproof, Scotch-Clad roof coating with lightweight, highly efficient polyurethane foam insulation. One-part, elastomeric roof coating is quick and easy to apply with conventional airless spray equipment, and cures in the presence of atmospheric moisture to form a seamless film that "breathes" to allow damaging moisture to escape from within the roofing system. The two-coat system provides excellent weathering, and a toughness that withstands light maintenance traffic. Polyurethane foam has the highest insulating value of any insulation now available.

Materials. This is a two-component system.

1. Polyurethane foam–used for thermal insulation. This foam has the highest insulating value of any insulation now commercially available. Sprayed at the recommended 3-lb/cu ft (16 kg/m^3) density, it exhibits an excellent strength-to-weight ratio and resists normal maintenance traffic.

2. Scotch-Clad roof coatings are one-part elastomers that cure in the presence of atmospheric moisture. They apply quickly and easily with conventional airless spray equipment. The cured film has excellent weathering properties with toughness that withstands maintenance traffic.

Qualities.

1. Lightweight–allows flexibility in building design.

2. High moisture vapor transmission rate–the cured film "breathes," allowing damaging moisture to escape from within the roofing system.

3. Seamless–foam and coating are applied continuously, eliminating seams which can be points of water entry and heat loss.

4. Application versatility–polyurethane foam combined with Scotch-Clad roof coating is especially adaptable to unique roof structures, such as folded plates, hyperbolic paraboloids, domes, etc.

5. Fire resistance–American Society for Testing and Materials ASTM E 108/UL 790 Class A fire rating is available. This rating requires 50 lb of roofing granules per 100 sq ft (2.5 kg/m^2).

6. Weather stable–Scotch-Clad roof coatings maintain toughness, adhesion, and elastomeric properties after extended exposure to UV and freeze-thaw cycles.

7. Guaranteed–material and labor are guaranteed jointly by 3M Company and the licensed applicator.

8. High thermal efficiency–polyurethane foam has the highest insulating value of any commercially available insulation.

9. Repairs easily–any necessary repairs to damaged areas are accomplished easily and quickly.

10. Resists chemicals–effectively resists oils, gasolines, alkalies, and cleaning compounds.

11. Variety of colors for coatings–gray, black, red, green, beige, and custom colors.

Dow Corning Corporation

General Use. Dow Corning 3-5000 silicone/urethane roofing and insulation system combines the insulating values of lightweight, rigid polyurethane foam with the excellent weather resistance and durability of silicone rubber to create long-lasting, dependable, economical roofs for reroofing jobs as well as in new construction.

Materials. Two to 3 in. (50.8 to 76.2 mm) of foamed-in-place polyurethane foam (rigid) over a variety of roof decks or old roofs; topped with two

coats of silicone rubber, which protects the foam from UV radiation and chemical degradation; roofing granules are optional.

Qualities.

1. Leakproof.

2. Lightweight–saves on construction costs.

3. Saves in energy consumption–sometimes 20 to 30 percent because of high insulation qualities.

4. Saves in heating and air-conditioning investment.

5. Saves in old roof removal and downtime since it can be directly applied over existing roof.

6. Meets all UL 790 requirements for Class A construction on noncombustible decks at slopes up to 3 in. per foot (250 mm per meter) and for Class B construction on noncombustible decks at slopes to 4 in. per foot (333 mm per meter).

7. Meets Factory Mutual Class I approval for remedial application over existing roofs on a steel deck.

8. Seamless construction–because this monolithic, self-flashing system eliminates fishmouths* and overlaps, most common water entry points are eliminated. And since the foam is closed-cell, water cannot travel horizontally through the system.

9. Provides a breathable silicone membrane instead of trapping water in substrate, thus preventing substrate damage, blistering, and loss in insulating efficiency due to moisture saturation.

10. Durable.

Irathane Systems, Inc.

Irathane Weather/Flex Plus.

1. General use: Irathane Weather/Flex Plus is an elastomeric, protective coating system for outdoor rigid urethane foam applications.

2. Materials: Weather/Flex Plus is a two-coat system consisting of a base coat, Irathane 300, and a color-stable, weather-resistant top coat, Irathane 394. Irathane 300 base coat is a two-component polyurethane elastomer (catalyzed urethane) consisting of a polymer component and a unique curative solution, which are blended in equal volumes during mixing. The mixed material cures by means of an internal chemical reaction which is not dependent on exposure to moisture or solvent evaporation. Irathane 394 top coat is a two-component color-stable aliphatic polyurethane elastomer with exceptional weatherability which chemically bonds to the Irathane 300 base coat. Three volumes of polymer are blended with one volume of curative during mixing.

3. Qualities:

a. Durable, waterproof, and weather-resistant.

b. Provides exceptional protection from the damaging effects of sunlight, water and ice, oxidation and ozone attack, thermal shock, and airborne pollutants and vapors.

c. Excellent resistance to physical abuse such as hail and foot traffic.

d. Can be used for both new construction and reroofing jobs.

e. Lightweight.

f. High insulation value, especially when used over an existing roof where no tearoff is required.

g. Coating available in a wide range of stable colors.

h. Maintenance-free service life.

i. The breathability of the system allows the relief of internal vapor pressure, while maintaining an effective barrier against water intrusion.

j. Optional Irathane Treated Granules can be applied to the top or color coat to provide additional protection against physical abuse, enhance appearance, and increase resistance to weather. Available in many attractive and stable colors.

k. Irathane issues a 5-year guarantee on both labor and materials for the Weather/Flex Plus roof.

NOTE: Irathane Systems also manufactures variations of the Weather/Flex Plus coating system: Weather/Flex, Endura, Endura/Flex, and Endura/Flex Plus. All are catalyzed urethanes, and differ mainly in their specifically recommended uses.

*Buckling of material between fasteners.

The Neogard Corporation

"Elasto-Gard" Roofing System.

1. General use: Elastomeric coating for polyurethane-foamed roofs; ideally suited for large roof areas with a minimum pitch of 1/8 in./ft (3 mm/m).

2. Materials: Polyurethane foam is applied to the roof deck; next, a liquid-applied neoprene base coat is applied, followed by a top coat of Hypalon (Du Pont trademark).

3. Qualities:

a. Job-proven performance of 15 years.

b. Dependable waterproofing with maximum performance.

c. Hypalon top coat is available in a wide range of colors and has a good moisture vapor transmission (M.V.T.) factor.

d. Hypalon (specially formulated chlorosulfonated polyethylene) provides outstanding resistance to ozone, sunlight, heat, and chemical oxidation.

e. Neoprene (a synthetic rubber–polychloroprene) provides excellent toughness and resilience. Good elastomeric properties.

f. Lightweight.

g. Flashings are formed of elastomeric material and become an integral part of the roof membrane.

h. Economical. Savings can be achieved because of the deadload-weight on structure, elimination of costly flashings and counter flashings, reflection of radiant heat load (when white surface is used), and low amount of maintenance required.

i. Dependable application assured; licensed applicators are required.

"Perma-Lon" Roofing System.

1. General use: Elastomeric coating for polyurethane-foamed roofs; designed for flat or sloping roofs.

2. Materials: Polyurethane foam is applied to the roof deck, followed by a liquid-applied urethane base coat, and finally a top coat of Hypalon.

3. Qualities:

a. Urethane base coat offers outstanding abrasion resistance, hardness, and impact resistance; in addition, it is less sensitive than most coatings to high humidity during application.

b. Urethane base coat has high tensile strength and elongation properties, providing maximum resistance to traffic.

c. Available in UL 790 Class "A" fire-rated formulations.

d. Hypalon top coat provides a choice of colors for the system and has excellent weatherability.

e. The combination of these synergetic coatings provides maximum insulation protection as well as an extremely smooth finish (average thickness is 38 dry mils) over the polyurethane foam.

f. Easy application.

g. Excellent moisture vapor transmission rate.

h. Lightweight.

i. Flashings are integral to the system.

j. Economical.

k. Licensed applicators required.

"Butyl-Lon" Roofing System.

1. General use: Elastomeric coating for polyurethane-foamed roofs; can be applied to dead-flat roofs as well as vertical surfaces.

2. Materials: Polyurethane foam is applied to the roof deck, followed by a liquid-applied butyl base coat, and finally a top coat of Hypalon.

3. Qualities:

a. Butyl has the lowest permeability rating of any elastomeric coating–used wherever extreme water vapor drives are anticipated (essentially serves as a vapor barrier).

b. Use of a Hypalon top coat provides a wide variety of colors.

c. Even though butyl can serve as a vapor barrier, it still retains its elastomeric properties.

d. Butyls are available in either standard or fire-rated formulations.

e. Hypalon top coat provides outstanding resistance to ozone, sunlight, heat, and chemical oxidation.

f. Lightweight.

g. Flashings are an integral part of the system.

h. Economical; savings can be achieved through deadload-weight on structure, elimination of costly flashings and counter flashings, reflection of radiant heat load (when white surface is used), and the low amount of maintenance required.

i. Dependable application assured; licensed applicators are required.

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